APPLIED ECONOMICS FOR ENGINEERS

BY

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PREFACE

In observing, over a period of years, the progress of a large number of engineering graduates as they enter the various fields of technical endeavor, I have been impressed with the importance not only of a clear understanding of economic principles, but also of the application of these principles in the many branches of technology. An attempt has been made in this book to provide the student in engineering with an introduction to the practical aspects of economics, basing this upon conditions and problems which he is likely to encounter in practice.

With a clear recollection of the kind of training received in college, and some vision of present-day needs, the younger technical graduate who gives this matter serious thought can provide a viewpoint of distinct value. For this reason, I have obtained, from many such graduates, ideas which have been most valuable in the preparation of this book. To them, my hearty thanks are due.

In the preparation of this book, two young men, one from the West and the other from the East, have shared with me their spare time and talents. Mr. F. Wendell Beichley has assisted with tireless energy and loyalty in the preparation of the manuscript and in a search for reference aids. Mr. Donald W. Brous has likewise assisted in developing a substantial share of the material contained in several chapters. To both, I am deeply indebted. These young men have also been of material aid in providing the viewpoint of the recent technical graduate as he becomes engaged in the practical affairs of industry. Appreciation is expressed to Mr. George D. Wilkinson, Jr., of Newark, New Jersey, for his contributions to ideas and problems in production.

Though fundamental principles remain largely unchanged, their application in technical fields continually assumes new aspects. For this reason, a particular effort has been made to assist the instructor in establishing the habit, on the part of the student, of consulting pertinent and worthwhile articles in current periodicals.

BERNARD LESTER

MAPLEWOOD, NEW JERSEY, 1939.

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CHAPTER I

ECONOMICS AND THE ENGINEER

THE APPROACH TO ECONOMICS

As we proceed in our study of economic principles applying to the work of the engineer, we are going to depart from those methods commonly used in a discussion of abstract economic principles, and see if we can determine the practical problems which the technical graduate encounters as he takes up work in a variety of branches of industry. When we find out what these are and study all the factors that are necessary in their solution, we find that some definite and understandable economic laws exist.

Further, we will find that, although economic laws are fundamental and established, their application is continually altering, because we live in a world of rapid change. Consequently, current literature in the fields of engineering, industry, and trade provides many articles which illustrate the changing application of these economic laws. Reference has been made to many of these in the text. As time passes, many more will appear in new issues of the same or other publications; by reference to them, one can keep abreast with what is happening in the world today and get a better grasp of how fundamental economic principles are applied to current engineering problems.

THE ENGINEER IN INDUSTRY

The young engineer today makes his start in industry at any one of a thousand points. It may be in some branch of technical research, design, construction, operation, or production. Or, again, it may be in connection with some phase of distribution or maintenance of technical products or services.[1]

The young engineer may, on the other hand, start his work with some privately operated company, with a company engaged in some

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[1] Reference: "Engineering Opportunities in Manufacturing," T. C. Johnson, *Electrical Engineering,* February, 1939, p. 72.

form of public service regulated by government, or with a form of government itself.

First of all, he encounters people in addition to things, and finds that organizations proceed and function in an orderly or disorderly way through the responsibilities and efforts of people. He gets a glimpse of fixed responsibility handed down from employer to employed, by various steps, and he sees that progress depends not only upon technical knowledge put in motion through carefully worked-out plans, but also upon a recognition of economic values and satisfactory relationships existing between individuals who, of necessity, must come in contact with one another. He finds that, as an individual, in most instances, he can accomplish little, but as a part of an organization with assigned responsibilities whose actions as a group are controlled he can accomplish much. Although he may at first feel himself pretty much like a tooth in a gear, he soon discovers that neither things nor people are fixed, but that he is living in a world of rapid change where unlimited possibilities exist for doing things in a better way. He finds that violent differences may occur in opinions held by individuals with whom he comes in contact, and that often their opinions are not based upon facts. Having had experience with formulas and laboratory experiments, he sees a greater need for facts upon which to base plans—dealing not with moving bodies which may be weighed and calculated, but with thinking human beings, with potential reactions.

As the young engineer works with materials, machines, and individuals he sees that an outlay of expense is required to accomplish a result, and that the return from the result must be sufficient to compensate for this outlay. Besides the cost of those operations that go on within the plant itself, he enjoys, as he works, the benefits of light, heat, and ventilation, and perhaps he shares in sickness, accident, or similar benefits; thus he comes to realize that economic factors enter into supplying these things, also, and that they cost something to furnish. Perhaps an extension to the plant is in progress, or a new boiler house may be necessary, and he wonders where the money for this comes from. Is it out of profit, out of capital, or is it borrowed? If out of profits, can the company afford the improvement? If out of capital, why should the money be allotted to this particular item? If borrowed, how is this managed with existing financial institutions? The young engineer learns that, after all, capital [2] is necessary, and that capital must earn a return on its investment.

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[2] Reference: "Utility Engineering and Capital," C. W. Kellogg, *Electrical Engineering,* January, 1939, p. 3.

The young man, himself, is anxious to obtain a higher wage, and perhaps soon feels convinced that this should be forthcoming. He sees about him workmen of all ages, some highly skilled and others doing routine duties, some progressing by developing new ideas and others following a track laid down. He attempts to evaluate, according to the individual, the relative value of labor, the measure and rate of compensation, and the length of working hours. Thus, he is thrust intimately into an economic problem involving a measure of performance so vital in its solution to society.

Any work this young engineer attempts is laid out to some degree by plans and systems based upon facts gathered together and principles established by experience. He finds out that not only plans, but also useful records, are essential.

Although trained in the exact sciences, the average engineering graduate plunges into the world of industry to find that economic factors combined with technical factors determine procedure, and success in carrying out any plan revolves about satisfactory relationships with people. Engineers, in contributing so liberally to the material advance of civilization through invention and mechanization, are faced with meeting those problems of an economic and social nature [3] which this advance has brought about.

Many young engineers as they advance come more intimately in touch with problems relating to distribution. They find that decisions and plans even in this field are largely made on a basis of engineering economy. Because an engineering training teaches one to deal with facts, in addition to theories, and involves economic planning, many men trained in engineering have assumed positions of business leadership. With our highly developed ability to invent, design, and produce, the question of economic distribution has assumed a position of the greatest importance, requiring a high degree of scientific knowledge. After all, the customer supports the business, and satisfactory customer relationships are essential.

The engineer, in his work, therefore, continually encounters *physical, economic, psychological,* and *social* laws. These laws he finds to be interrelated,[4] because in operation they react on one another. For

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[3] Reference: "Social Horizons of the Engineer," Harry J. Engel, *Civil Engineering,* November, 1937, p. 763.

[4] The engineer decides that the design of a gear case which is a part of the driving mechanism of a domestic washing machine and built in large quantities can be improved by making this part of pressed steel rather than cast iron. Cast-iron gear cases have in the past been used, and the manufacturer has operated his own foundry largely for this purpose. This decision may be a perfectly sound one from the physical laws involved in the selection and forming

successful procedure, all four types of laws must be recognized and their reactions understood. In this course of study, we shall deal particularly with *economic* laws and their application in the field of technical products and services.

Accomplishment proceeds, in the eyes of the young engineer, through the bringing together of four outstanding elements—*capital, management, labor,* and *materials*—and decisions are based upon what we consider to be relative values.

In becoming a part of our economic system as a producer, one must treat the matter of economy objectively. The problem which faces all of us sooner or later, as we pass from a period of training to a period of producing, is that of being able to furnish more economically some class of goods or service which possesses increased utility to those to whom it is furnished.

Economics has been defined as the social science that deals with human interest from the viewpoint of value capable of monetary measurement.

Value is that which makes anything useful or estimable. It has been compared with energy, for, if destroyed through consumption in filling a want, it is replaced by new energy resulting from consumption. Oil, put in an engine to lubricate it, in time is partly or wholly destroyed. Through its use, however, new values have been created in the form of power. Coal fed to the stoker under a steam boiler is

of materials. However, what effect will this change have on production costs, selling price, and profits, according to the laws of economics? What effect will this change have upon the appearance of the machine and consequently upon its commercial acceptance according to the laws of psychology? Will this change require closing down the foundry, and, if so, what can be done to furnish employment to the molders, according to the social laws?

Some years ago a manufacturer of luminous-faced watches employed a number of young women to paint the figures on the watch face. In doing so, they moistened the brushes with their lips, and it was claimed this produced serious physical injury. The processes had to be changed, involving new physical laws to meet social requirements.

With the increasing cost of coal and the decreasing cost and greater availability of fuel oil according to economic laws, engineers were driven to apply physical laws in the development of oil burners.

A manufacturer of typewriters redesigns the model, altering primarily only the exterior housing of the machine. The appearance is improved, based upon the style of the day. Much greater acceptance is created for it, leading to greater volume demand requiring a larger capital expenditure for tools and equipment, such changes being brought about by an understanding of human reactions based on the laws of psychology.

destroyed, but steam is produced for power in its various useful forms, and other values are created.

The *utility* of products and services in the eyes of the economist is the measure of their capacity to satisfy human wants. The engineer has created numberless new utilities.

The *price* at which products and services are sold represents their monetary value. The level of the price depends upon both the utility of the particular article and its scarcity, assuming that prices are not artificially controlled.

A trained engineer is responsible for the operation of a foundry for the production of iron castings. He must know the characteristics of the materials required and the specifications to be met, based upon engineering data. He must know the technique which goes with all phases of foundry practice and operations. If, however, his understanding were limited to these factors, the foundry would be considered a failure. He must concern himself with other factors, for if this foundry is to be successful it must show a profit on the capital invested in it.

Hence, the engineer must study the *utility* of the castings produced. Do they meet the requirements of the prospective customer? Is the demand a stable one, or might not the purchaser of iron castings resort to welded structural steel instead of cast iron to meet his requirements?

The *price* to be obtained for castings becomes of vital importance, for this factor, together with the volume of output, determines the amount of money that will constitute the entire income. The cost of making castings becomes, then, a subject of intense interest, and it is soon discovered that a variety of expenses, including such items as labor, machinery, depreciation, upkeep, and interest on invested capital, go to make up the cost.

This illustrates clearly, then, how this engineering executive must grapple with problems not only of an engineering nature but also of an economic character, if he is to be successful.

One reason why an engineering training has been considered useful to one entering business is that the engineer deals with physical problems in an analytical way. Dealing with materials and forces, he must reduce them to quantitative and qualitative terms, rather than simply describe them, and must proceed by steps of evaluation to reach certain definite conclusions. All engineering accomplishments, to be useful, must take into consideration, in addition to physical facts and laws, economic facts, laws, and trends.

THE AMERICAN VALUE SYSTEM

The American economic system existing in this country so far has provided that the individual can acquire and accumulate capital through a profit-making system. The corporate instrument is only a legal means by which a group of individuals can do this, through units of stock ownership. The system, operating according to certain rules, both legal and ethical, protects the individual in exercising his own initiative and industry in profit-making, as well as the accumulation and ownership of capital. Such a system is based upon the theory of individual competitive effort and reward applying thereto.

The American economic system, however, cannot be completely described as either a capitalistic system or profit system. Many economic units exist with very small capital, as for instance a firm of consulting engineers, and we all know that those requiring a large capital may operate, often, for long periods of time without making a profit. Capital and labor are far from the only elements of our economic life. We can more correctly describe this as a value system, for the results of our economic system consist of *physical products*, such as locomotives, houses, and machines; *financial rewards*, such as salaries, wages, taxes, and dividends; and *social values* resulting from an improved use of materials and services.[5] Since we do not easily

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[5] It is also well to point out that those things which we create can also be applied to the detriment of society and the individual. We can create implements of war or instruments for the use of criminals. Scientific accomplishment itself can be utilized to destroy society, or destroy the individual. Gilbert Murray has recently pointed this out in weighing the advantages and disadvantages of technical accomplishment:

> In this machine age man has had to pay a heavy price for the help given him by his machines. Take a well-fitted modern observatory; a telescope with a very large lens, a clockwork arrangement enabling it to follow exactly some particular part of the sky, a fine photographic apparatus to record the light of the stars, even stars quite invisible to the eye. A man looks at the photograph and discovers on it a new star. A great achievement, but due chiefly to the machine, not the man. Such a man is not using nearly as much mind, as much thought and brain power, as an ancient Greek or Chaldean astronomer who with no instruments at all observed and calculated nearly right, if not quite right, the main movements of the heavenly bodies. Think of a stupid fat man driving fast in a beautiful motor car which he does not understand; or the millions of clerks who are carried blindly to their work every day by train or bus: they are not using nearly as much intelligence as the man of a hundred years ago, walking on his own legs, looking about him, noticing plants and trees and birds. No doubt immense skill and brain power have gone to making the instrument—the telescope, the motor car, or steam engine; but the instrument, when made, actually diseducates the user. It enables him to do what he wants or get where he wants, almost without using his mind or brain or limbs at all. And if he need not use them you may be sure he won't use them. From: "The Engineer and Trends in Economic Thought," Frank B. Jewett, *Electrical Engineering*, August, 1938, p. 340.

recognize social values, compared to physical products and financial rewards, it is easy to fail to visualize or evaluate their importance. Yet these social values are created before you obtain the products or the profits, and many of them continue to endure indefinitely. Social values are many. Let us consider just a few which the young engineer may create as a part of his effort. In the research laboratory, discoveries are made of new products and processes. In spite of any advantages accruing to the engineer or his firm under patent protection, which is only temporary, society at large benefits by his accomplishment.[6] The same is true in respect to a designer of a machine or structure involving new ideas or the engineer who develops a new process or method of production. We readily see what is actually done, but the far-reaching influences we fail to grasp even during the present—let alone in the years to come.

Nevertheless, the urge to produce under our economic system comes largely from the profit motive, and our system provides for a reasonable profit to successful suppliers of a product or service. Manufacturing plants cannot continue to operate unless supplied with adequate capital. Profits attract capital; losses repel it. Security of a fair wage to labor depends upon an adequate supply of capital, just as the use of capital depends upon a supply of labor. The system under which we have progressed in the past has, therefore, been one of creating values through the cooperation of individual initiative with capital in the creation of values beneficial to all. Such a system has made possible certain abuses, which have to be curtailed and eliminated by a set of rules sufficiently flexible to provide for change to meet altering conditions.

INDUSTRIAL DEVELOPMENT

It was quite natural that the people of this nation at the time it was formed possessed much of the spirit of the pioneer and adventurer. Large unsettled districts of rich land lay before them, and hidden raw materials of untold value were theirs. For those with the pioneering spirit, nothing could be more inviting. During the first century of the nation's history, men were largely engaged in discovering what was available and finding a way to transport it and to use it according to the somewhat crude methods of the times.

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[6] Think what Thomas Edison accomplished for society by directing his inventive genius toward the development of the electric light, or George Westinghouse, to the development of the air brake. The profits which came to these men or to the companies they established were infinitesimal compared with the benefit to society.

As we approached the close of the last century, less opportunity existed for pioneering of this sort. What was readily available in land and raw materials had been recognized, had been viewed in the advance of science at the time, and had fallen into the hands of aggressive or fortunate individuals or groups.

This same spirit of pioneering and adventure of necessity asserted itself in a new field. Instead of being directed toward discovering available lands and material it was now applied through a further study of their nature, to finding new uses for them in their existing or modified forms. The laboratory and the factory became the sites for pioneering and adventure. To these were later added fields of activity involving markets and distribution, to support volume production. Out of this modern pioneering has come a most complicated industrial empire, which is evolving in greater variety and in larger quantities, products for use in every phase of daily life; it is also producing wholly new problems concerning human relationships.[7]

Our industrial development has been driven forward, very largely, by the *profit motive*. However, it is sometimes hard to tell whether the impulse to accumulate wealth has sprung from a desire to enjoy the pleasures and comforts wealth may bring, or whether the chief regard has been the esteem attached to wealth as a recognized measure of human accomplishment. Obviously, the profit motive does not govern all the actions of the individual, for these may be directed by other interests such as patriotism, fear, desire to help, and affection. In our study here, we are interested only in the economic effect of such motives, should they exist.

In tracing the industrial development of this country since its inception to the present time, we find certain outstanding factors which have characterized our advance. They are:

The increased use of tools and machinery.
The increased use of power.
The adoption of mass-production systems.
The adoption of mass-distribution systems.
The specializing of human effort.
A changing attitude toward consumption.
The creation of markets.

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[7] Mr. Clarence Francis, President of the General Foods Corporation, has pointed out that the greatest growth in our industrial system took place from 1870 to 1930. During this period of 60 years our population doubled, production increased 7½ times, and the volume of trade multiplied 15½ times. In spite of a rapid mechanization in industry, the proportion of the population gainfully employed was 32 per cent in 1870 and 40 per cent in 1930.

The stimulation of invention through research.
The development of large economic units.
The growing wage scale.

In viewing these ten important factors, we find that they are closely related. For instance, the increased use of tools and machinery could not have come about to the great extent it has without the development in power facilities, and vice versa. Mass production and mass distribution, likewise, had to go forward hand in hand, and the creation of markets had a great influence in this connection.

H. G. Moulton, "Engineering Progress and Economic Progress," *Electrical Engineering,* May, 1937, p. 510.

1. The Increased Use of Tools and Machinery. Man has been defined as an animal which uses tools.[8] From the earliest historical records man has used implements, and as time and invention advanced these became more specialized and efficient, and were devoted to a greater variety of purposes. Hand tools were first employed for simple operations, and their variety increased with the discovery of their necessity and utility and the increased skill of the workman. With the advance of trade and growth of demand, large quantities of duplicate articles were required so that a workman had to repeat the same operations. With a division of labor, by which each workman became expert in a particular operation, an opportunity came for the ingenious development of machines which would perform simple operations automatically and in rapid succession.

For instance, in the cutting of metals and other materials, the workman held the tool and applied his power and skill to it in following the work. With repetition of operations required, the machine was introduced between the man and the work, which held the tool and guided it, as either the tool or the work moved. Continuous improvement has been made in the machine. Power has been applied to it. Its work has become much more accurate. The functions of a single machine, though highly specialized, have been broadened by adding to the number of operations performed. Thus where formerly several machines arranged serially performed operations in sequence, many of these operations have now been combined into one machine. Machines have been improved, so that, together with an improvement in

[8] "A tool is but the extension of a man's hand, and a machine is but a complex tool. And he that invents a machine augments the power of man and the well being of mankind."—Henry Ward Beecher.

the materials worked upon and with the introduction of new materials, higher operating speeds are gained. Furthermore, improvements have made it possible for machines to follow a predetermined pattern and even check themselves.

In fact, a machine can be built for almost any purpose including an almost endless variety of operations performed in series. The problem is not so much one of devising the machine, as in determining whether and when its use is justified.[9] Will the demand for the product made by the machine remain staple as to character and volume? Is the loss suffered by scrapping the old machines justified? These and similar questions must be answered through economic studies to which judgment must be applied.

The advance in the use of machines has therefore been characterized by:

A transfer of skill from the worker to the machine.
A transfer of power from the worker to the machine.

There appears to be no limit to the work which machinery may take over from man. However, it has been the rule that the more simple and monotonous tasks that man has had to do are the ones that the machine first takes over. But in this process of transfer of skill and power to the machine, other monotonous tasks are being created, with a higher degree of subdivision in labor. Whereas formerly production depended upon the skilled mechanic, who could lay out the task of creation and perform the necessary operations, his place is now taken by the machine operator, whose work is reduced largely to operations of a routine nature. Such a situation has led to

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[9] An interesting mathematical justification for the increased use of machines and power is found in the editorial entitled "1 Man = 420 Kwhr," appearing in *Power*, November, 1938, p. 49 (587). In substance it is this:

> Man, as a machine, is worth very little. Consider a husky man who every day performs the equivalent of carrying a 50-pound load 3000 feet up a mountain slope. His day's output is 0.057 kwhr. Working 50 weeks per year (2 off for vacation and sick leave), and 5 days per week, he will generate approximately 14 kwhr per year, or 420 kwhr in a working lifetime of 30 years. If he were to sell his energy at the low wholesale rate of 3 mills per kwhr (for which hydroelectric power can, in some areas, be purchased), he would earn just $1.26 in his lifetime. Giving him a retail rate as high as 6 cents per kwhr, he would still be worth only $25.20, so far as his 30-year output is concerned.
>
> Hence, man cannot directly compete with power-generating apparatus, but he can do something a machine cannot—he can think. Thus, he is better fitted to design and operate machinery to take his load up the slope than to carry it himself, and better fitted to build and operate power-generating equipment than to generate power. Though machines are better fitted to do the physical jobs than man, man must direct them, and it is here he finds his most useful place.

social problems which continue to baffle us, for the mind of the routine worker tends to become narrow and distorted.

The various steps which have taken place in a transfer of skill and power from the worker to the machine, combined with a division of labor and the development of production systems, are well illus-

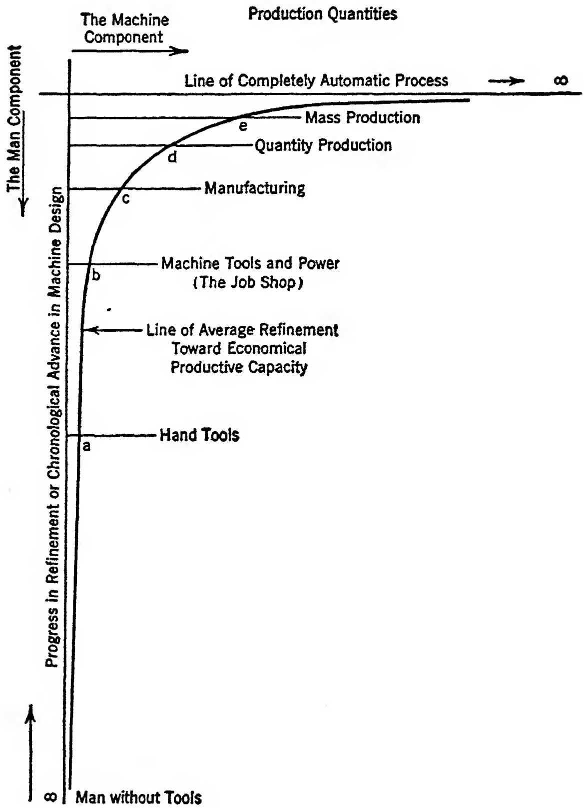

FIGURE 1. The changing relation between man power and machine power in the development of production. From "Marketing Industrial Equipment," Bernard Lester, McGraw-Hill Book Co., Inc., New York, 1935, p. 46.

trated in Fig. 1 by Edward Payson Blanchard of Bridgeport, Connecticut, in a chart of progress he has prepared. This applies particularly to mechanization through the use of metal-working machinery.

The various steps as illustrated on this chart may be described as follows:

a. Men used *hand tools.*

b. Men established *job shops* wherein they worked together, mostly with small tools, each individually completing the finished article made.

c. Machines were developed to direct the tool, and men were segregated in their work, so that, to a degree, one man performed an operation or a series of operations toward the completion of the article being made. *Manufacturing,* as we now understand it, had its start in this way.

d. *Quantity production* came from the use of a number of highly perfected machine units, and an arrangement of these in a factory to permit a flow of work from one to another, forming the necessary parts and finally leading to an assembly of the completed article.

e. In many instances, today, *mass production* is obtained by making not only the individual units or steps automatic in their operation, but also by linking them together so that the entire operation is largely automatic. Thus, a shop has become the equivalent of one automatic machine.

From a study of advance along these lines, we find that there has been continual progress in these directions:

The machine itself has become increasingly automatic, in that it has required less attention on the part of the workman.

The machine has been developed to perform a greater number of operations at the same time, so that one machine has included the operations which were formerly performed by two or more machines arranged serially.

The machine has continually been redesigned to produce a greater volume due largely to increased speed in operation.

The machine has become continually more specialized in purpose and accurate in performance.

Although the development and use of machinery has been largely responsible for the physical progress that has been made in this country, the results of mechanization upon the social condition of our people have presented problems which are most perplexing.[10] Through years of experience, a factory or office worker becomes skilled in performing certain operations. Speed and skill have been encouraged by management by all sorts of schemes of compensation. Suddenly, perhaps, machines become available which will largely or wholly replace the individual operator and his services are no longer required, at least for the class of work previously done. Thus we have a condition of technical unemployment, resulting from the substitution

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[10] Reference: An interesting editorial on what power and mechanization has done and can do is "Man *vs.* Power," Philip W. Swain, *Power,* June, 1938, p. 49 (299).

of machine skill and machine power for man skill and man power. Unquestionably, opportunity ceases for the trained worker, and he is forced to seek other forms of employment for which he has developed no skill. Readjustment to new kinds of work and new surroundings is most difficult, and a widespread atmosphere of unrest, dissatisfaction, and instability is created.

A broader view of the picture shows us that, by means of the machine, the workman's production is increased and products and services are created more cheaply to be available to a larger circle of consumers.[11] New opportunities are created for employment[12] else-

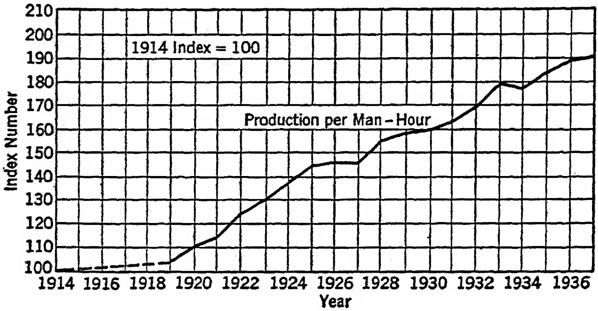


FIGURE 2. Index numbers[13] of production per man-hour in the manufacturing industries of the United States, 1914 to 1937. From *Factory Management and Maintenance,* November, 1937, p. 80.

where since these products must be transported, sold, and maintained, and the utilities created cause demands for complementary utilities.

In most of our older manufacturing industries, over a period of

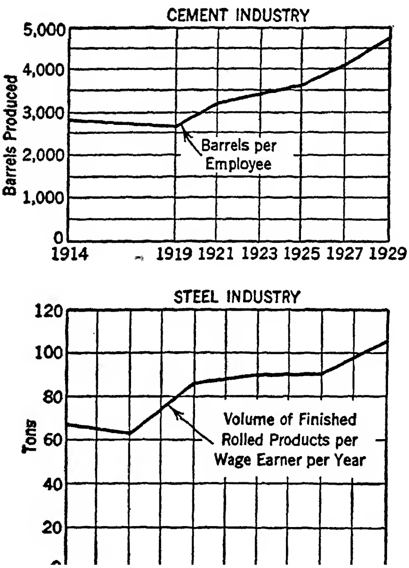
[11] References: "What Machines Mean to Bill Smith," *American Machinist,* September 21, 1938, p. 830L; "Mechanization Pays the Worker," Paul G. Hoffman, *American Machinist,* September 22, 1937, p. 830.

[12] No better example of creating work by introducing machinery in the place of man power can be found than the automobile. It is said that the present low-priced car could not be produced today according to manufacturing methods in vogue 25 years ago, for less than $10,000. Labor has actually been eliminated in the factory, but, by the use of machinery in mass production, the price of the automobile has become ridiculously low and its performance improved, so that the demand for it has increased by leaps and bounds. This has led to the creation of labor, not only by the suppliers of materials such as sheet steel, glass, and rubber, but also by those who use and maintain automobiles. Road building and maintenance, wayside garages and service stations, and provisions for tourists have all been stimulated, and the American people have learned to travel and spend.

[13] For the student not familiar with the derivation of index numbers for the purpose of presenting statistical information, there is a short topic dealing with index numbers in Chapter VII, Statistical and Accounting Methods.

years, the output of the individual worker has steadily increased, as the introduction of machinery has proceeded. Figures 2, 3, 4, and 5 will illustrate this condition, although other factors, such as decreased output compared to capacity following variations in business activity, may produce a conflicting effect in certain years.

Mechanization has produced another effect which is largely economic in character. In the early days, the factory was little more than a building providing benches and other simple furnishings



in the cement and steel industries.

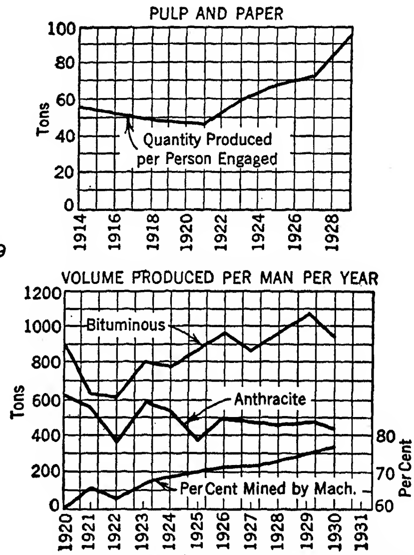


FIGURE 4.* Production per worker in the pulp and paper industry, and the bituminous and anthracite coal industries.

* Figures 3 and 4 from "Marketing Industrial Equipment," Bernard Lester, McGraw-Hill Book Co., Inc., New York, 1935, p. 37-8.

wherein the workmen could busy themselves with small tools or simple machines. As machines were substituted for workmen in furnishing skill and power, a larger amount of invested capital was required, and a much larger proportion was devoted to machinery and equipment than to land and buildings. Furthermore, with the rapid and continuous improvement in machinery and equipment, and the necessity for each manufacturer of keeping such apparatus up to date in order to maintain a competitive position in the industry, this mounting

capital investment has become less stable and secure.[14] As we shall see later, a large share of modern machinery and equipment soon becomes obsolete or outmoded, and must continually be replaced.[15]

In addition to this, the structure housing the production equipment and those that operate it has gone through a transformation. Better

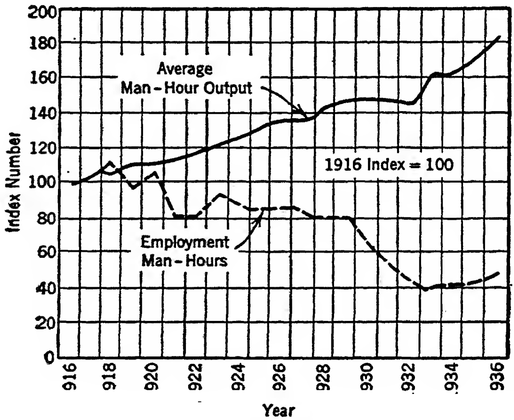


FIGURE 5. Employment man-hours and man-hour output, Class I railroads of the United States. (Excluding principal salaried employees). Reproduced from *Monthly Labor Review* (published by the U. S. Bureau of Labor Statistics), July, 1937, p. 79.

and more suitable buildings are provided, and these include provisions for greater safety and comfort of the worker. Elevators, for instance, are required, heating and ventilating equipment is now necessary, and improved lighting systems are employed. Facilities for the distribution of power must be provided, as well as the distribution of water with necessary plumbing fixtures. All such changes[16] as

[14] Many years ago, the author went through a small factory, in a country town, devoted to the annual production of many thousands of large umbrellas—then used to mount on the drivers' seats of horse-drawn delivery or farm wagons. Even then this factory was highly mechanized, and only five people were required to keep the machines going. At that time, two thoughts stood out in the author's mind—the wonders of mechanization and the instability of *the continued growth* of this particular industry, on account of the advent of the automobile.

[15] Mr. W. J. Cameron, of the Ford Motor Company, recently stated that, during the seven years from 1931 to 1937, his company had scrapped $175,000,000 worth of machinery and replaced it with improved machinery for which they paid $217,000,000.

[16] The modern factory building usually requires power, heat, light, ventilation, transportation, water, compressed air, and waste disposal.

these have increased the capital investment in factory building structures.

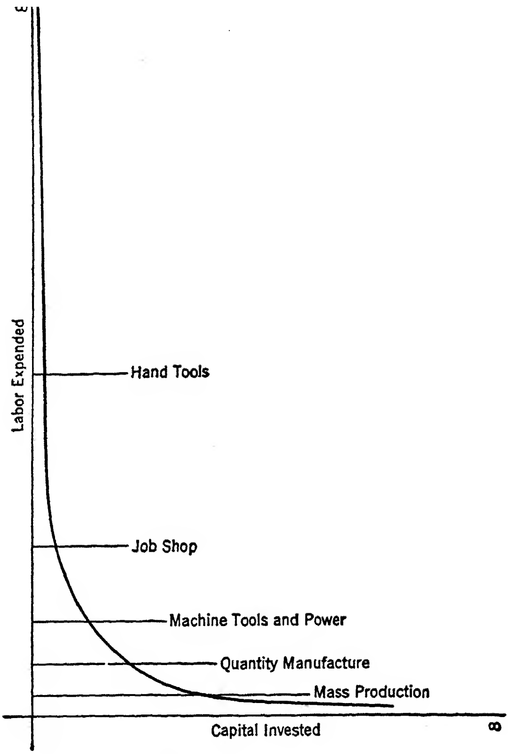


FIGURE 6. The changing relation between capital invested in machinery and labor expended. From "Marketing Industrial Equipment," Bernard Lester, McGraw-Hill Book Co., Inc., New York, 1935, p. 48.

Figure 6 shows this great increase in capital investment[17] as the mechanization of industry has progressed from the age of hand tools down to the present machine age.

2. The Use of Power. The increase in use of power for mechanical purposes, light, heat, and communication has been an important factor in our industrial development.[18] The discovery of electricity marked an outstanding advance because electrical power can be transmitted long distances without serious loss in energy.

The principal direct sources [19] are:

Falling water.

Steam generated by fuels.

The combustion of fuels within an enclosed power-producing mechanism.

In the advance of industry through the use of machinery, power

[17] Mr. W. J. Cameron of the Ford Motor Company, for instance, has pointed out that the inner shell of a hubcap for automobiles made by machinery costs 12 and a fraction cents—but it requires $13,328 in dies to shape it, and the automatic press to stamp it costs $30,770, to say nothing of the costs to house, maintain, and provide the power to operate this equipment.

[18] It has been estimated that in this country, at the present time, the mechanical power used is the equivalent of the average of 50 slaves, working full time, for each inhabitant.

[19] Other sources of mechanical power, such as the windmill and heat engine, have been used to a minor degree.

for driving the machine has been an important contributing factor. The problem of economically transmitting power from its source to the point at which it is to be used has become increasingly important as manufacturing plants have multiplied and grown in size. Various mechanical contrivances such as moving rods, circulating liquids, cables, belts and pulleys, and gears, have proved useful for only very short distances. The discovery of electricity, together with the invention of generators, transformers, distributing apparatus, motors, and a means of controlling them, has proved of enormous value in making possible the transmission of power and its utilization even in very small units. Electrical power can be efficiently generated in large quantities at a favorable point and transmitted and used almost anywhere.

The development of the internal-combustion engine, however, has been outstanding in the development of industry. With its inherent original weaknesses—including poor speed regulation and torque characteristics, noise, excessive weight, and the production of dangerous waste gases—one might think its use would be quite limited. Engineering skill has perfected it and devised simple and successful means of applying its power. Particularly is this true in the field of transportation,[20] agriculture, and construction, where an independent source of power has proved so useful, and the connection to a central source of power so often uneconomical or impossible. The Diesel engine, for instance, is being used to a greater extent to furnish large units of power to industry.

Figure 7 shows the changing nature of primary[21] power and the proportion of the total primary power that each kind represents. It does not, however, tell us anything of the total growth of power. For such information, we find there is but one reliable source, that being the generating capacity of the electric light and power industry. This capacity represents a large percentage of the total power capacity of the country, and it also provides the only available accurate infor-

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[20] At one time in France, the speed record up to that time for a passenger automobile was made by an electric vehicle! Subsequent to this, concentration of engineering skill upon the development of the internal-combustion engine and its application to the passenger automobile proceeded at an enormous rate, encouraged by the fact that distilled fuels gave a large source of power within very small space and weight limits. In spite of its distinct limitations, which have been largely overcome through engineering concentration yet unparalleled in industry, it soon outstripped both steam and electricity.

[21] Primary power refers to the form of power actually applied to driven machines in industry generally. Obviously, the total volume has increased year by year, and this chart illustrates only the proportional values for the four common forms of applied power.

mation on total power. Figure 8 indicates how the installed capacity for power has grown since 1902, and the proportion of this capacity provided by each of three types of primary mover. It will be noted that, despite economic conditions in 1938, the installed capacity of public utilities was at an all-time peak.

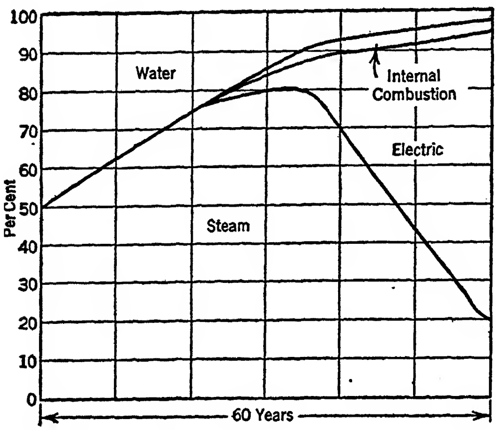

FIGURE 7. The changing character of primary power developed, over a 60-year period.

Figure 9 is interesting from the standpoint of seasonal and holiday variations, showing graphically how the demand for public-utility power varies throughout the year. It will be noticed that, for all four years, despite the relative magnitudes of each year's output, the peaks and valleys follow very nearly the same trend.

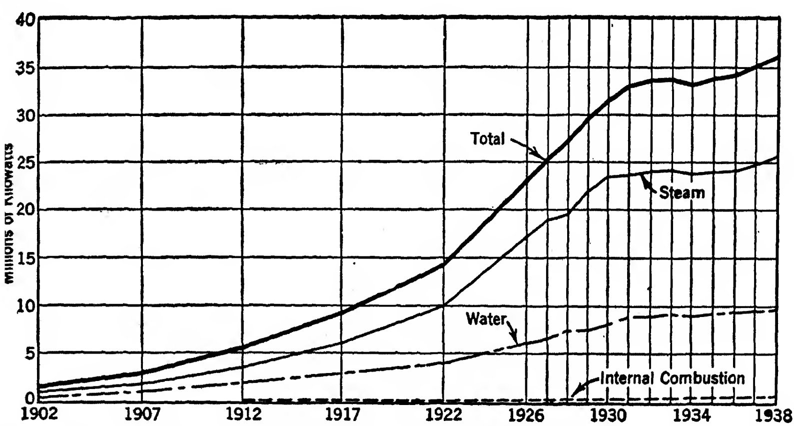

FIGURE 8. Installed capacity, by type of prime mover, of the electric light and power industry. From *Electrical World,* January 14, 1939, p. 73 (97).

The use of power for light and communication through the medium of electricity, and for heat through steam and electricity in all sorts of industrial processes, has represented a phenomenal engineering accomplishment.

In the industries, the development of the machine and the use of power have gone hand in hand, depending upon each other, and contributing to our economic and social problems. Power has become to a large extent a necessity, for on it often depend those earlier fundamental necessities such as food, water, clothing, shelter, and fresh air. It now is a commodity to be furnished as a public service, and as such has entered into our political, economic, and social life.

The way in which the power-driven machine in recent times has progressively developed is illuminating. The mill or factory, after

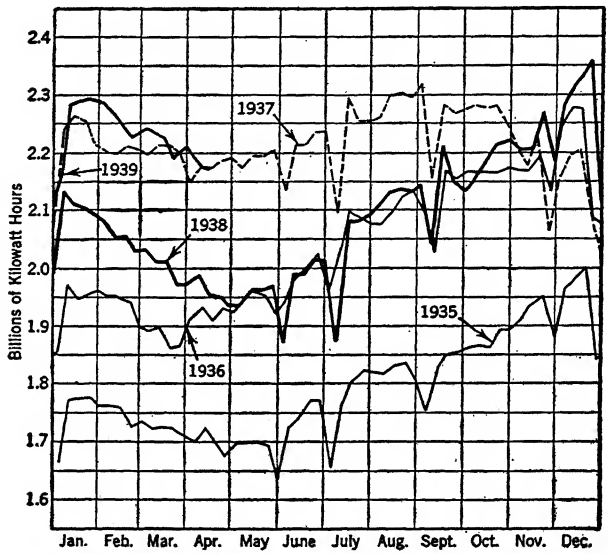

FIGURE 9. Output of energy by the electric light and power industry, 1935 to 1938, showing seasonal variations. From *Electrical World,* April 22, 1939, p. 61 (1179).

the advent of the steam engine, was usually operated by one engine which drove the industrial machines usually through a system of countershafts and belts. It was discovered that it was more economical in many cases to operate only a small group of machines from one source of power because that made the entire power system more flexible. In some few instances this was actually done by applying a small steam engine, to which steam was piped, to a group of individual machines.[22] No great progress was made in this direction,

[22] Such an installation existed several years ago at the plant of the Westinghouse Air Brake Company, Wilmerding, Pennsylvania, where engines were located throughout the factory to operate small groups of machines, all fed from a centrally located boiler.

however, until electricity was introduced and the electric motor and control were made available. This step permitted operating a group of machines together from one motor, which could be shut down, or operated without driving the whole system of line shafting in the plant. The next step was to operate some machines, at least, by individual motors which were mounted on the factory floor and connected to the individual machines by belts or chain drives. As effort continued to make the factory a safer place in which to work, more cleanly and more roomy for the operators, someone conceived the idea of mounting the motor directly on the machine, thus making the machine an independent power unit. As the machine was the subject of further development, including not one but several operations, the power units or motors were built directly into the machine, and applied in multiplicity to the individual operating elements of the machine. Perfection in electrical controlling apparatus permitted the control of the various motors from one point, according to a predetermined cycle of operation.

There is not an industrial or commercial enterprise that does not use power. Many of the economic problems encountered by the engineer deal with questions relating to the generation, transmission, conversion, measurement, application, and control of all forms of power. The selection of the most suitable form and source of power presents complex economic problems involving such matters as original investment, depreciation, obsolescence, upkeep, and other factors of marginal importance, requiring exact information and reasoning, as well as the exercise of judgment. Various forms of power are continually struggling with one another for adoption, largely supported by common suppliers of power, or by those who build particular classes of machinery and equipment. The engineer is faced with problems relating to the selection of the most economic source and forms of power, and also, especially, with a fair and simple means of determining an equitable charge for furnishing power from an independent source.

3. Mass-Production Systems. The mass-production plant, an American institution, is based upon a high degree of specialization of work by machinery and upon standardization of parts. Mass production involves making, by automatic machines, parts which are exact duplicates, and assembling them at any convenient location, by specialized machinery which is also largely automatic, into the completed product.

The advantages of mass-production systems consist principally of:

Building products in large quantities, as the name "mass" implies.

A very low labor cost.

An almost perfect uniformity of the finished product.

A uniformity of component parts which permits quick and satisfactory repair of the product anywhere, or economical replacement of small articles of low cost.

The disadvantages or limitations of mass-production systems are:

An enormous outlay in specialized machinery, which, when changes in the product occur introducing new processes, causes heavy capital loss.

A system of production where the failure of one operating department may seriously interrupt the entire productive process.

A system of production which, when loaded lightly, means loss rather than profit, and consequently requires a large and steady load.

A system of production usually possible only for large operating units where disadvantages due to size exist.

A closer study of mass production involves one in a consideration of many social as well as economic factors. Mass production is the latest step in specialization of labor, in the reduction of cost, in the increase in investment, and in the interdependence of individual shop departments and perhaps scattered plants.

4. Mass Distribution. Mass distribution is the child of mass production, but in this instance the child supports the parent. When a mass-production system is set up for a given product, it is relatively easy to increase production by speeding up or increasing the size of the manufacturing units or establishing additional duplicate units in favorable locations.

Furthermore, with a mass-production unit established and working, ample opportunity exists for further study of time-saving schemes which continually make further cost reductions. In most industries and upon most products, productive capacity is closely fixed but sales volume presents wide variations, so that the burden of balance between production and sales usually rests upon sales, and production schedules are set on the basis of what can be sold. Thus, with productive capacity usually in excess of average demand, the selling branch is put to it to maintain an increased volume of sales. This branch of the business is driven forward by a desire to obtain lower costs, to make lower prices to stimulate additional business, and to obtain a larger share of expense available for sales promotional effort.

In developing mass distribution, these factors characterize progress to date:

> The selecting and establishing of sales outlets where the product will be available for purchase in a manner easy, pleasant, and satisfactory to the customer.
>
> The creation of demand and the cultivation of customer acceptance through all the devices of sales promotion and advertising that can be conceived.
>
> Providing a pricing policy which seeks to sell goods to the user at continually lower prices.
>
> The mechanizing of all routine matters relating to the distribution of the product.
>
> Providing, in most instances where the purchase involves a sizable financial outlay for the individual user, a means of financing the purchase.

Mass production continually calls for mass sales, and mass sales call for lower prices attained through greater mass production.

The possibilities in mass production and mass distribution and the reaction between the two have created a condition which has led many an industrial executive to expand beyond the point of sound economic operation. The condition is much like that which confronts the traveler on the desert. The mirage appearing before him in the distance leads him to rush on to a well-watered and green valley, which, however, disappears before his eyes as he advances. Extreme pressure from the distribution officials for lower costs brings the insistence from production officials for greater sales volume, and vice versa. As a result, the enterprise, guided only by an increase in production and distribution, becomes topheavy and unstable, and is liable to fall to pieces when clouds gather on the business horizon.

5. Specialization of Human Effort. During the Colonial period, every town had its carpenter, mason, millwright, wheelwright, blacksmith, and weaver, together with representatives of many other trades. As manufacture proceeded through mechanization, and as industry grew, a higher degree of specialization of individual effort took place. New industries sprang up, and existing industries split according to the various specialized processes that developed. Factories became more highly specialized in their work, and this specialization has continued to a greater degree to the present day, in spite of the fact that business organizations, toward the close of the past century and until recently, followed a policy of expansion by acquiring and combining small factory companies under one general management.

The growth of mechanization and the factory itself had a pro-

found effect upon the worker. On one hand, it changed the individual, who had previously been skilled with his hands in performing an operation or series of operations required in making an article, into a machine operator, usually classified according to the machine he was skilled in operating, such as a lathe, punch press, loom, linotype, or what not. On the other hand, it introduced a large number of skilled employees, occasioned by a more elaborate and extensive factory system, whose work related to such matters as supervision, process records, production records, wage rates, and machine maintenance.

This transformation has come about in almost every industry. The mechanic as he was known 50 years ago is almost extinct. He could read a technical drawing, gain a complete conception of the article to be made, lay out the work to be done in wood or metal, form the parts with simple machine tools, fit them together with expert filing and scraping, and, in the end, produce a complete and finished article. Today, he is no longer required to do more than operate a machine or a whole battery of machines which, in the manufacture of a given part, are largely automatic.

In the building trades where each building project is "tailored" and much of the work is done on the ground, there is still need for skilled workmen of the type of the mechanic, but the work of the carpenter, glazer, bricklayer, and so on, has been reduced to a great degree by introducing factory-made parts into building and by the development of more elaborate and accurate tools which may be moved to the point of operation.

Organized labor has been rather slow to recognize this change, but in late years we see a strong movement toward the formation of a vertical labor structure rather than a horizontal one.

A mental review of the large number of specialized processes typifying factories will show us how completely specialization of human effort has advanced and, as a result, with our multiplied requirements as consumers, how completely industries and individuals must now depend upon one another.

6. A Changed Attitude toward Consumption. Contrast the attitude and habits of the individual purchaser of a buggy 50 years ago, with those of the buyer of an automobile today. To the average purchaser, at that time, buying a buggy was an important matter, undertaken only at rare intervals. Particular attention was given to the lasting qualities of the article and, once acquired, it was used only when quite necessary, and kept in good repair. Today, the purchaser of the automobile is chiefly interested in performance and appearance.

He knows that changes will take place within a few years which will outmode the present car, and an exchange system exists which will enable him to acquire the latest models. Little attention is paid to the facilities for maintenance from his own hands, for he depends on the availability of nearby efficient and cheap specialized maintenance service.

The psychology of consumption has gone through a fundamental change. Today, we recognize that, to gain the advantages that come from production, we must encourage consumption. The principle of "keep what you have as long as it can be of possible use" has been replaced by the principle of "use freely what you have purchased and discard it when something better and more attractive is available."

Mechanized gadgets of all sorts have entered into our business and social life. They have influenced our ideas and conceptions. The child today uses technical terms [23] unknown to our grandparents. Our imaginations are stimulated by mechanical tricks provided that they contribute to our comfort and convenience. Our minds are open to new technical accomplishments, and our social standing, to a degree, is influenced by the extent to which we use them. The latest in design and completeness attracts us, and we spend willingly today to obtain as necessities those things which were novelties and luxuries a few years ago. Thus, the demand for technical products, representing a market for the manufacturer, has come into existence from every class of business unit, as well as from the institution, club, home, and farm. Public acceptance has been distinctly sympathetic and every successful producer has energetically cultivated it.

7. The Creation of Markets. Emerson has expressed the idea that, if one were to build a mousetrap of the highest quality possible, sooner or later the buying public would beat a path to the door of the manufacturer in its anxiety to obtain the article. This was doubtless true before means were found for informing the public of the availability of the product and its merits and uses, but today this statement requires modification to be applicable.

Today the greatest skill and vast expense are required to influence purchasers to recognize a worthwhile product and adopt a favorable attitude toward it and the producer. Many products are offered for sale that are in advance of public taste and desire, and through all

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[23] A child, nine years of age, was recently observed drawing a good likeness of an air transport in flight. Someone questioned the fact his plane had no wheels. His ready reply was, "Oh, this is a Douglas—a DC-3—and they have retractable landing gears."

forms of sales promotion, the manufacturer endeavors to create the demand.[24]

Pride, affection, fear, and other human qualities are appealed to in such promotional effort to a degree never before heard of in our industrial history. For example, factory management is taking greater pride in the appearance of the plant machinery and equipment, as well as plant layout. Those who sell such equipment make a particular effort to encourage and develop the elements of human appeal and pride in order to increase the sale of new products offered. Tire manufacturers have resorted to a combination of fear of accidents and affection for the members of one's family in selling new tires which are supposedly good insurance from blowouts. Many other examples may be brought to mind where human emotions have been played upon in selling.

8. The Stimulation of Invention through Research. Most earlier inventions were made by such people as mechanics, barbers, carpenters, and other artisans, for the trained engineer as we know him today did not exist. We are inclined to assume that the discoverer of a principle or the inventor of an article deserves the entire credit for the accomplishment. Usually this is not true, for those who follow and carry the initial accomplishment through its various stages to the point where its practical use is widespread deserve a large share of credit. Very few major inventions come into practical use in less than

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[24] Many examples could be cited of the ridicule heaped upon fundamentally new ideas in apparatus and the stories of the Wrights in Dayton, Ohio, and Henry Ford in Detroit are typical.

Many years ago, a Mr. Spangler of Canton, Ohio, now deceased, suffered from asthma. He noticed that the disorder was more severe when his wife swept the floor. In his cellar, he rigged up a carpet sweeper with a motor-driven fan, so assembled that the dust was drawn into a cloth bag. The contraption was ridiculed by his neighbors. Mr. W. H. Hoover, whose company was engaged in making saddles, however, saw not only the future for such a device, but also a waning demand for saddles. He assisted Mr. Spangler in his work, and finally undertook building and perfecting suction sweepers, with the result that the perfected Hoover suction sweeper finally became an established type and make of machine in the field of vacuum cleaning.

George Westinghouse, in originating the air brake, sought the interest of the railroads toward its trial and adoption. At the time, he was selling his replacer and frog to the roads, which gave him an opportunity to meet and try to interest many railroad executives in his brake. Some of them simply lacked the time to listen; others listened—only to ask such foolish questions afterwards that Westinghouse knew they had grasped none of what he had just said. One day Westinghouse found a ready listener in "Commodore" Cornelius Vanderbilt. But, at the end of the explanation, Vanderbilt, in a way of directness for which he was famous, simply said that the subject was far too imaginative to be given serious attention, and that he had "no time to waste on fools."

ten years after the initial discovery, and most of them require a much longer period.

Our earlier inventions were usually the result of individual study and personal accomplishment with resources of the most limited sort available.

Today, on the other hand, all progressive companies carry on research, and many of them maintain large, well-equipped, and expensive organizations for that purpose. It is fully recognized that, in order to maintain a leading position, a manufacturer must make improvements in his product and must develop new uses for it.[25] New products,[26] too, to be added to those already being made, particularly if they complement existing products, are desirable. Other avenues of attack in the field of research are improving and lowering the cost of making products which are already available, so that we find extensive effort expended upon materials, methods, and processes used in manufacture.

9. The Development of the Large Economic Unit. It will be noted that, so far as mechanization is concerned, the whole tendency of mass production and mass distribution has been and is toward an increase in the size of the economic unit. Where such large units have been managed in a manner which protects the interests of the owners, workers, and customers, results have been achieved which, doubtless, would have been impossible by other means. Only within the last few years has a reaction set in toward this increased size in the economic unit, and such reactions have been due even more to social reasons than to economic ones. The power held by the management of large economic units, often shared in by large financial interests, has sometimes been abused, and public opinion has asserted itself in a way to control growth and operating policies. Particularly has this been true of those who render a product or service which is universally required.

Companies engaged in manufacture or the rendering of a service have usually grown in three ways:[27]

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[25] Reference: "Coal Develops Unexpected Possibilities," *Coal Age,* February, 1939, p. 76.

[26] In its 1937 financial statement, the E. I. du Pont de Nemours Company makes the significant statement that, in 1937, 40 per cent of its business came from products unknown 10 years ago.

[27] Examples of concentric growth are provided by the du Pont Companies, General Electric Company, Jones and Laughlin Steel Company, Chrysler Corporation, and many others which have grown, largely through doing a greater volume of business in their chosen fields.

Examples of companies which have grown horizontally to a considerable

Concentrically, i.e., as the result of an increase in the quantity or variety of the articles produced or services furnished.

Horizontally—by consolidating with other manufacturers whose products or services are complementary.

Vertically—by reaching forward toward the market and controlling distributing outlets, or backward toward the suppliers and controlling sources of raw materials and other industrial products usually otherwise purchased.

10. The Growing Wage Scale. It will be seen that, through the use of powered tools and machinery, the productive ability of the workman has been steadily increased. He is now equipped with many mechanical hands, which do more work, do it more uniformly and more accurately, and perform repetitious operations without fatigue. His job is to know what these hands can do, and to select, direct, and maintain them.

Tariffs on imported manufactured articles, established by our national government, have, through the reduction of foreign competition, raised the price of the article for the purpose of increasing wages, as well as raising revenue—thereby elevating the living standard of the American workman. The increasing cost of labor has been a constant incentive to mechanize our industrial systems for creating goods and services. From this has come the elimination of labor at the point of manufacture, already described, together with technical unemployment as mechanization has proceeded.

The wages paid and the hours of employment are, therefore, vital subjects, involving both economic and social problems and laws. The trend toward *shorter working hours per week* and higher rates of income is quite definite. For example, in the building trades,[28] the

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degree, by absorbing or consolidating with companies in the same field or allied fields, are the American Radiator Company, which consolidated with the Standard Sanitary Company, the American Blower Company, and others to form the American Radiator and Standard Sanitary Company; the National Dairy Products Company; and the American Telephone and Telegraph Company.

Examples of companies which have extensively grown vertically, by controlling sources of materials or distributing facilities, are Anaconda Copper Company, United States Steel Corporation, and International Harvester Corporation.

None of these companies have grown only in the way indicated, but these three methods of growth are characteristic of the development of large industrial corporations.

[28] *Monthly Labor Review,* August 1937, p. 299, Table 8. It will be noted that, since these data were prepared, our national government has established a legal maximum number of weekly working hours and a minimum wage scale. (See *Monthly Labor Review,* July, 1938, p. 107.)

distribution of weekly working hours among the total workers is as follows:

10.9% of all employees work less than 40 hours each week.
70.0% of all employees work 40 hours each week.
10.4% of all employees work between 40 and 44 hours each week.
8.7% of all employees work between 44 and 60 hours each week.
0.4% of all employees work 60 hours or more per week.

Another trend is shown in the manufacturing industries, where, with a base index of 100 in 1914, the index of average hourly earnings has risen to 276 in 1937, while the index of purchasing power [29] represented by these earnings is 192, as compared to 100 in 1914. These figures show clearly how, with a shortening of weekly working hours, the standard of living [30] has risen in the past 25 years. Such a trend is highly desirable, according to popular opinion, and the chief argument being concerned with how suddenly wages should be increased and working hours shortened.

THE ENGINEERING PROFESSION [31]

The original demands upon engineering skill came in the field of military activity, and the military engineer was first to be recognized. The civil engineer, in contrast to the military engineer, took his place as construction work became more common and as cities were built which required streets, water systems, and later sanitation. Then followed the architectural, mechanical, mining, marine, gas, chemical, and electrical engineers. To this list may be added many more special branches of the profession, and subdivisions, as industry became more highly specialized. For instance, in recent years, from the chemical engineering group has come the metallurgical engineer, and from the electrical engineering group, the transmission, the radio, and the illumination engineers.

Modern production methods have introduced engineers who find their places cross-sectionally in many industries, as the safety or the production engineer.

In the earlier days of our industrial development, many of the

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[29] The purchasing power of money wages is termed "real wages." A chart showing "real" weekly earnings in various industries for 1929, 1932, and 1937 is shown on page 65, *Factory Management and Maintenance*, February, 1938.

[30] Reference: "Standards of Living," Gerard Swope, *Atlantic Monthly*, March, 1938, p. 341.

[31] Reference: "The Nature of Engineering," Clair V. Mann, *Civil Engineering*, April, 1937, p. 260.

leading engineers in industry operated independently as consultants in their various fields, and as such served their clients much as the physician and attorney. Although in several industries[32] this is still true, it has been the practice of many of those companies engaged in manufacturing, mining, transportation, and public utility work to employ much of their own engineering talent. Many manufacturers of technical products have employed men to perform an engineering service for those who purchase goods requiring some form of service to insure their proper application and use.

The application of the mind trained in engineering to the development of new products, and better and cheaper ways of making these products, has assisted in raising the standard of living of all classes of our population.[33]

Reference

T. R. Agg, "Engineering in This New Era," *Civil Engineering,* November, 1938, p. 711.

BUSINESS SUCCESS AND FAILURE

It may well be asked what determines the success of an economic unit constituting part of our industrial activity? Assuming conditions wherein economic units can flourish, there is only one answer—*capable management.* Almost all failures may be traced to poor management, and many accidents that cause loss or wreck companies could have been guarded against, or entirely prevented, by good management.

The management of any company engaged in the production of goods or the furnishing of services is faced with such factors as the following:

A good location for manufacture and distribution.

A sound financial structure which provides adequate working capital[34] and necessary cash and reserves.

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[32] Consulting engineers still occupy an important position, particularly in those industries which involve complicated and highly developed processes, such as the manufacture and processing of pulp and paper, mining and smelting, foods and chemicals, and textiles, as well as in planning structures of all sorts where the engineering and construction functions are often performed by one company.

[33] It is estimated that in 1938, of all wired homes and farms in the United States—of which there are approximately 23,420,000, 94% are equipped with electric irons, 51.6% with mechanical refrigeration and 57.5% with electric washers. This is indicative of how drudgery has been reduced and more healthful conditions promoted in rich and poor homes alike, through the development and price reduction of these technical aids. (Data from *Electrical Merchandising,* January, 1939, p. 20.)

[34] Reference: "What is Working Capital?" *American Machinist,* February 8, 1939, p. 37.

A policy regarding expansion that is reasonable and conservative, and one that is regulated according to a careful study of probable future conditions.

A credit and collection policy which takes customers, as well as sound business practice, into consideration.

The high quality of product made or services rendered, and the facilities for maintaining this quality.

Limiting the efforts of the company to those fields for which it is best equipped to serve.

Establishing a means of performance by which reasonable commitments are made, and these commitments met.

Strict compliance with all laws and ordinances established by the various forms of government.

Analysis of all operating costs, and the establishing of prices which will render a reasonable profit.

The establishment of conditions under which all employees will be happy, healthy, enthusiastic, and prosperous, both under normal conditions and those of emergency.

Protection of property by insurance, or otherwise, against unforeseen circumstances which are liable to occur.

Equipment for doing the best work at the lowest cost.

Strict control of expenses of all kinds.

A policy of informing the public about the company, its operations, and its products, upon the basis of existing facts.

A policy and a plan for investigating and evaluating probable future conditions which will affect the progress of the enterprise, including the market.

Such items as these could be expanded, but they are the more essential factors that breed success. The fact that there are so many business failures [35] in this country make is increasingly necessary that further study be given to the management of business enterprises.

THE ENGINEER AND BUSINESS

The young engineer, in assuming his duties as an employee, can expand his possibilities for service through the performance of his duties in an efficient and complete way. Such growth usually takes place in two directions: through a better understanding of the policies, organization, and principles of operation of the company for which he works; and by a better understanding of what is taking place specifically in the field of operation in which his employer is engaged, and generally in the entire field of economic activity.

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[35] See Fig. 1, Chapter IV, for curve of business failures in the United States.

Viewing, for the moment, the company which employs him, the engineer will find, in most instances where a company is engaged in furnishing a product or a service, nine distinct functions to be performed. They are:

Financing is required, and financial operations are necessary and important.

Research is necessary, both as to material things and markets, and also as to methods of accomplishment.

Design—whether it be a machine, bridge, transmission system, or determining the kind of service to be rendered.

Production, or the preparation, fabrication, and furnishing of the goods or services to be rendered.

Purchasing—the buying of products or required services.

Distribution—gaining an acceptance for the product or service, and getting it into the purchaser's hands.

Collection, or the obtaining of currency for the product or service rendered.

Maintenance of that which has been furnished to purchasers.

Employee relationships—attending to those personal matters between company and employee.

These functions vary in importance, depending upon the kind of business in which the company is engaged, but, nevertheless, they serve as a basis of study in widening the scope of interest of the individual in preparing him for further responsibility. In a study of these functions as applied to the company which employs the individual, he can well determine in his own mind what he would do if he had the responsibilities of management. From this point, he can extend his study to other companies that are engaged in a similar activity, and thus encompass the particular field or industry—considering it as a whole. Since industrial activities or integrated industries are mobile and change with altered forces from within and varying conditions from without, the point of view must be continually broadened by a better understanding of what has occurred in the past, and what altering forces are in the making for the future.

Growth of the individual and the ability to accept increasing responsibility comes not only from a greater knowledge of the particular industry in which one is engaged, but also from a greater knowledge of business conditions in this country and abroad, and the ability to interpret those facts and statistics which become currently available from day to day.

BUSINESS CYCLES

In considering the engineer's opportunities to study general business conditions and to apply this study to his own company, the subject of business cycles[36] is encountered. The business cycle, in itself, is interpreted by a running record of business activity taken over the years. The usefulness of this record comes from the fact that it shows business cycles to have a somewhat definite frequency and intensity which, to a degree, is repeated. Therefore, it appears that the management of a company should be able to watch the progress of the existing business cycle and to apply the knowledge gained from a consideration of past events to the company's own planned activities for the future, thereby avoiding some of the ill effects felt during periods of overexpansion and of depressions. New and unknown factors, however, are being introduced, the probable results of which are most difficult to predict.

The Harvard Bureau of Business Research feels that the business cycle consists of five distinct phases, which appear in the same order for each cycle and are fairly consistent in length of time. These five phases may be termed:

1. Period of depression.
2. Period of recovery.
3. Period of business prosperity.
4. Period of financial strain.
5. Period of industrial crisis.

Management, by knowing the symptoms of each of these phases of the business cycle, is able to predict more accurately than otherwise the trend of the company's affairs.[37] Business conditions and business trends which go to make up the business cycle may be ascertained and interpreted from a large variety of sources, each being a running

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[36] Reference: "Engineers and Business Cycles," D. P. Morgan, *Chemical & Metallurgical Engineering*, January, 1939, p. 17.

[37] Management of manufacturing concerns must watch very carefully such items as collections, number and size of inquiries, liquid assets, purchase commitments, volume of finished and unfinished stock, and prices of required materials. Skill is necessary in sensing business changes early, and adjusting operations in such a way as to meet them effectively. Some companies discover themselves entering a depression with abnormally large stocks of materials and finished goods, or, correspondingly, entering a period of business expansion with an insufficient supply of these to enable them to capitalize on increased demand. Likewise, in financing an enterprise or an expansion, at certain times funds can be raised much more readily and cheaply, or bonds or stock sold more favorably, than at other times.

measure of a certain kind of activity. Such activities may include purchasing, finance, sales, employment, production, and many other significant items[38]—each of which is affected by business activity,[39] and hence may be used to show trends somewhat accurately. Besides the general statistical sources which give facts to enable the individual to reach more intelligently his own conclusions, there are available forecasting services of several varieties. Probably most accurate and important are the regular established forecasting services for which one must pay a fee, such as Babson's Reports or the Harvard Economic Service. There are also the publishers of trade papers and periodicals, as well as banks and investment houses, that offer a forecast service as part of their own news service. As the engineer assumes responsibility in the field of business, he will do well to investigate such sources as these and attempt to correlate the information he can draw from them with his other statistical data regarding the activities of his own concern.

Figure 10 clearly shows how widely business volume has fluctuated over the years since 1894. A brief study of this illustration will bring out the "recurring" characteristics of the business cycle.

It is impossible to even make an estimate of the loss which is caused by the extreme periodic variations in general business activity, and its effect upon efficiency in production and the condition of employees. One of the most important questions before engineers, as they encounter the broader phases of business, is stabilization.

Unfortunately, most nations advance or retrench in their economic development according to great waves, governed largely not by fact or reason, but by the influence of mass psychology.[40] Confidence in the future passes from one extreme to another, based not so much on logic as emotion. Our particular country is still quite young, and like a child jumps from one notion to another. Progress will come through

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[38] One company largely bases its forecasts by following statistical records of: (1) steel ingot production, (2) freight-carloadings, (3) bank debits, (4) stock-market prices, (5) Federal Reserve Board records of industrial production, (6) corporate securities issued for new capital, (7) United States exports, (8) building contracts placed, and (9) federal deficits.

Obviously, the nature of a company's business will determine the most useful statistical factors to select in establishing forecasts for future business activity. For instance, the supplier of equipment which is required for installation in buildings will follow those factors particularly affecting building programs.

[39] Reference: "The Index of Business Activity and How to Use It," *Business Week*, September 17, 1938, p. 35.

[40] "It is a common business failing to wait until a situation is overripe before taking action—to buy practically at the top of a boom and sell out at ebb tide." From "A Winter of Work," *Power*, August, 1938, p. 37.

a better understanding by all our people of what constitutes permanent values, and a greater ability to identify the true from the false.

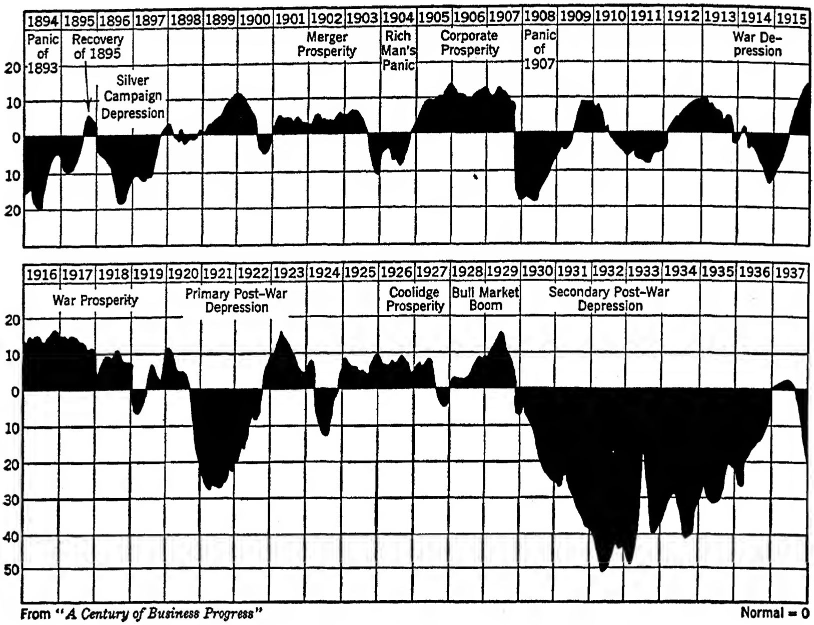

FIGURE 10. Business volume by years since 1894. Courtesy *The Century Press,* Toledo, Ohio.

The application of those principles which guide the engineer, and his methods of approach, hold out the greatest hope in gaining a more stabilized business procedure. It requires careful study, however, to apply such principles correctly to any given enterprise. Some products and services, for example, may find their greatest demand during times of depressed business activity. For instance, equipment manufacturers are likely to find the demand for renewal parts increasing at such times, since purchasers are unable to afford new equipment and must maintain the old.

Variations in the volume of business done in particular classes of technical products will follow, to some degree, general business cycles, but specific factors applying to one class of product or one industry may produce either unusual activity or inactivity, compared with general business conditions. Government programs for irrigation, sewage disposal, and flood control, for instance, may greatly stimulate

the demand for pumping equipment over certain periods. Periods of great industrial activity in the metal-working industry will mean that manufacturers of machine tools [41] are busy. Steam boilers will be extensively sold when public utilities are expanding and industrial and commercial building activities are pronounced.

The National Bureau of Economic Research of New York—a non-profit research society—has, for several years, been carrying on a study of the character of business cycles. The results of these intensive investigations are being published. The first volume to appear carries the title "Commodity Flow and Capital Formation." One startling observation is the great decrease which has occurred in the expenditures for new durable goods for purposes of production and new privately financed construction during the period of the business depression itself as compared with the period directly before the depression started in 1931. The following table [42] shows these figures:

EXPENDITURES FOR NEW PRODUCERS' DURABLE GOODS AND NEW PRIVATELY FINANCED CONSTRUCTION

Four-Year Period Previous to Depression		Four-Year Period During Depression	
1926	$14,839,000,000	1932	$3,560,000,000
1927	14,462,000,000	1933	3,379,000,000
1928	14,492,000,000	1934	5,662,000,000
1929	14,499,000,000	1935	5,999,000,000
Average	$14,573,000,000	*Average*	$4,650,000,000

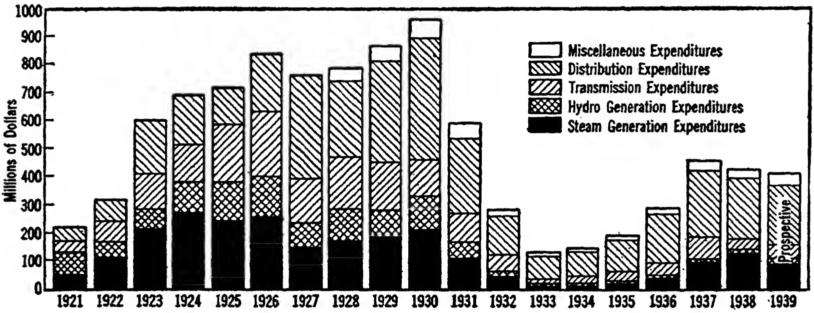

FIGURE 11. Capital expenditures of the electric light and power industry, 1921 to 1939. From *Electrical World*, January 14, 1939, p. 95 (119)

[41] The volume of machine tool business done in one month in 1933 fell to about 5 per cent of that of a peak month in 1929.

[42] Table from "One-Legged Nation," Harry Scherman, *Saturday Evening Post*, December 31, 1938, p. 32.

In brief, the business depression starting in 1931 was characterized by a lack of activity in the production of capital goods. Figure 11 serves to bear this statement out by showing the tremendous reduction in capital expenditures of the electric light and power industry during the depression as compared to the period previous to it.

Reference

Randall Hinshaw, "Rising Costs and Business Cycle Crisis," *American Economic Review,* December, 1938, p. 707.

CHAPTER II

PRINCIPLES AND METHODS OF PLANNING

THE PRODUCTION OF UTILITIES

Production is the creation of utilities. These may consist of *physical products* for all known uses, or *services* possessing no physical characteristics, but nevertheless useful in the creation of wealth and well-being.

In the creation of utilities, the problems encountered are of a physical, economic, and social character, and a program of procedure based upon known facts and known laws must be adopted, if these utilities are to be real and practical.

Planning an economic undertaking is for the purpose of determining:

Whether to proceed with the accomplishment of the undertaking.
When to proceed with it.
How to proceed with it.

Of course, one of these factors cannot be determined and a decision reached without consideration being given to the remaining ones.

The engineer engaged in technical work is called upon to assist or direct the gathering and putting together of facts upon which the plan of procedure will be based. However, such planning is by no means limited to the construction of machines or the erection of structures, for plans are of equal importance in connection with research, production, maintenance, and distribution programs, all of which require an economic viewpoint when relating to technical products. As we go on, we shall see how important systematic planning is to industry, and how the engineer fits into this function best.[1]

LAWS GOVERNING PROGRESSIVE THINKING

The individual has progressed over the centuries largely by imitation—copying what has been done before and becoming expert in the doing—and by developing new ideas interpreted into new processes

[1] Reference: "Engineers and Economics," M. E. Leeds, *Electrical Engineering*, February, 1937, p. 206.

and products by the "trial-and-error" method. As economic units have become more highly organized and individual effort specialized, the importance of greater efficiency in progressing from the known to the unknown has become more pronounced. Greater attention is therefore being given both to the methods by which the individual can proceed in progressive thinking, and also to the methods by which a group of individuals, each thinking along specially assigned lines, can as a group proceed toward a goal of accomplishment previously established.

Progress in this direction follows four steps in logical sequence, which must be followed both by the individual and the group:

> *a. Observation* is the first essential, and in this most of us as individuals are decidedly deficient. It is obvious that, to improve a product or an economic service, we must identify, recognize, and record every fact that can be determined regarding the product or service.
>
> *b. Classification* of these facts comes next, so that they will stand out before us in their true relation to one another.
>
> *c. Inferences or conclusions:* From these observed facts, properly arranged, progressive thinking calls for a decision in reaching *inferences* or *conclusions* which will give direction to the use of the information already determined.
>
> *d. Application:* The application or putting to use of the conclusion is necessary to complete the effectiveness of progressive thinking.

We find in industry many cases where progress is hindered or ineffective because of the individual's lacking an appreciation of the value of progressive thinking. Facts may be inaccurate or incomplete, which leads to improper conclusions.[2] On the other hand, all the facts

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[2] Many of our tentative conclusions prove false when all pertinent facts are determined and set down.

Some years ago, an automobile manufacturer was struck with the idea that by minor modifications the automobile engine could be made into an air compressor. If the automobile manufacturer were to supply air compressors in addition to automobiles, an advantage would be gained in the cost of manufacture of both air compressors and automobile engines. On further investigation, it was found that air compressors were required by the market in a large variety of sizes, with certain modifications depending, for instance, upon the pressures desired. It was also found that the method of selling and servicing air compressors was quite different from that required for automobiles, because the market differed. These and other facts proved the initial assumption to be incorrect.

All of us have looked upon glass as a very brittle substance, and could scarcely conceive of its being produced in flexible form. This notion has been proved false through the perfection of fabrics made from extremely fine and specially spun glass thread. Our original prejudiced notions have proved false,

may be there, but they may not have been properly arranged and evaluated, and hence the improper conclusions are reached. Again, the facts and conclusions may be correct but their application is not pursued to finality, so that progressive thinking has fallen short of fulfillment.

Suppose that the engineer is called upon to lay out a highway throughout a mountainous district. He must first gather complete information upon the contour of the country and its physical structure. He must find what equipment, materials, and labor are required to provide a highway suitable for the traffic conditions set down, and where these may be obtained. These and similar facts being obtained, they must be classified so that they can be compared in relation to one another and to the end sought. Next, from these facts definite conclusions must be reached, a type of highway and a route selected, and these conclusions applied toward the completion of the undertaking.

An engineer is called in to correct trouble experienced with the bearing of a steam turbine. He at once examines the bearing itself, measures the temperature, analyzes its construction, determines the grade of lubricant used and the means and extent of circulation, examines the surfaces and materials employed—in fact, obtains all observable facts. These facts are carefully tabulated, classified, and evaluated in relation to one another. He concludes that the bearing is properly proportioned and of ample size, that the materials are suitable and the lubricant the correct one. The trouble is due to an insufficient flow of the lubricant, and an application of the process of reasoning leads him to adopt a better method of forced lubrication.

NECESSITY OF PLANNING

Consider how weak would be the position of an engineer in charge of a factory power plant, if he faced the management of his company

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and we are accepting this product as of use in industry, for purposes for which it has heretofore been considered entirely impractical.

The idea that solidity was necessary for machinery involving moving masses was for a long time uppermost in the minds of designing engineers. Massive foundations and framework were thought desirable in order to kill shock and absorb vibration. Such conceptions have, to a degree, proved false, and flexibility and resilience and the introduction of pliable materials have come to be recognized as desirable.

Early electric irons were heavy and difficult for the housewife to move about, but there seemed no relief for her, since *weight* was believed to be the major element in a pressing job. After heavy irons had been used for many years, the realization came that, if the amount of heat were brought up, weight could go down, and so, today, we have light-weight, efficient irons.

with the simple statement, "We need new steam boiler equipment and I would like to receive authorization to purchase this and have it installed." Why is the equipment necessary? Cannot the present equipment be overhauled and kept? What will it cost? What will it save? How can we get steam while the change is being made? These and many other questions of economics would be asked by the management. Without a carefully worked-out plan dealing with fundamental matters, and such details as are necessary to establish them, the engineer's request would merit and receive no serious attention.

First, then, comes the establishment of the need, and this need may be created by existing conditions or by a new set of conditions. A new boiler plant may be planned, not because the old one is worn out, but because a new and much more efficient form of boiler becomes available.

Second, comes the development of a plan to meet the need, for the purpose of reaching a decision. This may come in several steps, with alternatives explored. Such plans as are necessary to arrive at a decision having been made, much of the work required for final accomplishment is done, and proves useful later, assuming that the project is to be carried through. Planning often proceeds by steps, checked by decisions to proceed further, in the interest of economy.

Third, comes the final decision to proceed, with the time set for starting and completing the undertaking.

In passing we should note that economic factors are not the only ones to receive consideration. The new boiler proposed may, for instance, involve a change in fuel employed, and an automatically controlled coal-, oil-, or gas-fired boiler may be proposed to replace one which has been fired by hand. By such replacement, the services of one or more men might no longer be required. Management is at once confronted with a social problem, in addition to an economic problem.

Usually, in physical planning, these elements are always present to some degree or other:

Space elements relating to location or physical dimensions or shape.
Materials to be employed.
Labor or human skill and effort necessary.
Financial investment initially or subsequently required.
The element of time.

The element of time may well be emphasized. We, as a people, have been rapidly becoming more "time conscious." Since our work is continually more cooperative in character, we must fit our move-

ments in with those of others. We proceed largely on schedule, and if we fail to perform at the right time, the results of our failure go far beyond ourselves and are multiplied. Orderly procedure requires that all operations be timed, not that each be done carelessly and in haste, but that all operations be coordinated to produce the best final result.

Time is an important element in all classes of construction work, because losses of some kind come into being as the result of any delay in the completion of the structure.[3] Usually, most structures must be completed at a certain date, and often a clause is inserted in the contract penalizing the contractor for any delay. On the other hand, too rapid construction work, as in a concrete highway or the foundation of a building where insufficient time is allowed for the concrete to set, may lead to material loss.

Many companies which build machinery and equipment have met with ultimate failure simply because they have not brought out new and improved lines of apparatus promptly enough to meet a competitive market. Similarly, many producers[4] have waited until competitors undersold them, before they set about designing equipment which could be built cheaply.

Many companies have also developed products so far in advance of the times that they had to be laid aside, and taken up later when the acceptance of the product was more clearly established.

Transportation companies find time the major element in their success or failure. People fly because the airliners span the continent

[3] The erection of a large office building in one of our cities, such as the Empire State building in New York, serves as a good example of the timing of materials, services, and specialized labor. There is seldom space for storage of materials upon the site. After the erection of the steel skeleton, certain materials are required in specific order and quantity, and they must be delivered at an exact time. Sufficient skilled labor of the particular variety required must be on hand. Services—such as electric power, elevators for haulage, water, steam for heating, telephone connections for communication, and sewage systems to dispose of waste—must be made available, not only to meet the final requirements of the complete building, but also for use while the building is under construction.

[4] One manufacturer of a small machine built in quantities lost money consistently on this item for twelve years. Originally, the machine sold for $15, but each year competition forced the price lower, and, through improved design, cheaper manufacturing processes, and increased quantity production, the selling price finally reached $5 per unit. Each year, this manufacturer reduced his cost, but only *after* having been forced to do so by competitors. As a result, costs went down *after* prices went down, instead of *before*, and there was a yearly loss instead of profit. A profit could have been realized had the manufacturer planned and carried out his cost-reducing programs in advance.

overnight. They use the railroad that has the fastest streamliner, or the most rapid freight delivery service. Transportation companies must reckon with time day and night in order to survive.

FACT FINDING

It is impossible to prepare a formula which can be followed for finding all the facts which the engineer needs in planning an engineering project, because of the wide difference in the nature of projects encountered.

These are the principal factors which must be considered in planning technical products:

Will it meet the performance requirements economically?
Will it meet all hazard?
Will it last in a state of efficiency?
Can it be easily and cheaply maintained and repaired?
Does it meet the five senses appeal?
What will it cost?
How long will it take to accomplish?

In proceeding with the design of a structure or machine, the engineer is at once faced with the necessity of finding facts relating to its use, manufacture, distribution, and maintenance.

Consider the engineer who is undertaking the design of a blower for the purpose of ventilating a building. A specification is prepared indicating the volume of air to be handled, pressure required, and temperature. Being an engineer, he knows definite facts about the laws relating to the movement of air. Information about the characteristics and costs of available materials is obtainable. These are all definite matters, and it would appear that the engineer could at once proceed to design the blower. Although it might be designed, the chances are that it would be entirely unsatisfactory to the manufacturer himself and to many users, distributors, or individuals in charge of maintenance, unless other factors than these were taken into consideration. The user might say that the blower was useless because it was noisy. The distributor might refuse to sell it because it was hard to ship and install, and unattractive in appearance. Those who might be called upon to maintain it might object on account of difficulty in lubrication. The manufacturer of the blower might object because it was designed without regard to economical manufacture, and the cost of producing it was entirely too high.

Thus, in planning the blower economic factors take precedence at every step in proceeding in the design based upon physical laws and materials. In short, the article produced does not have its full value of utility, and the profit motive for producing it is not satisfied, unless these factors are considered.

The engineer, therefore, is confronted not only with the necessity of information of an engineering nature, but information of an economic nature, for without economic facts, the engineering facts available to him become simply interesting playthings.

Facts necessary to establish an economic plan for a piece of equipment may in their nature be obtainable only from experience with similar equipment in service.

Information required for drawing up an economic plan for a structure such as a building[5] or a bridge may depend not only upon experience gained with similar structures, as regards, for instance, the life of certain materials, or long-time records of weather and water levels, but also upon *specific conditions* applying to the individual structure.

A recent example of failure of design to meet specific conditions was witnessed on a railroad during a flood. Supposedly, the new luxurious coaches were complete in every phase of design, but when the necessity of running the cars through high water was encountered, it was found that the air-conditioning apparatus mounted beneath the low-swung cars would not permit the operation of the coaches without damage to such apparatus. The older coaches, with their greater clearance, were able to operate in the water without damaging any suspended apparatus.

A certain type of material used in the heating elements of electric stoves was thought to be a very great improvement over any previously used material at the time it was incorporated into the design of the heating elements. Exhaustive tests seemed to bear this out. But, on distribution of the units, it was found that in a certain part of the country, owing to climatic and weather conditions, the units simply would not stand up even though everywhere else that they were introduced they were entirely satisfactory and an improvement over those made of the old material.

[5] Several years ago a large hospital in one of our eastern cities was almost completed when one half of the building settled about two feet. It was discovered that the architect who designed the structure had not made complete and adequate test drillings to determine the ground structure, so that suitable foundations could be provided for the structure, as a part of his design.

MAKING DECISIONS

One capable business executive, when confronted by the necessity of making a decision of consequence, draws a line down the middle of a blank page and puts down on one side of this line the reasons in favor of an action, and on the other side the reasons against it. Then, by balancing the two groups of reasons, he reaches an intelligent decision. Many of us are inclined to determine in our own minds the proper course to follow, and then attempt to justify it by selecting facts that will prove our case. Such decisions based upon "hunches" have only a gambler's chance of being right; they may be excusable as the answers to the personal problems of the individual, perhaps, but not to the economic problems which face the engineer. Engineers are usually employed by business organizations, and their decisions must be as nearly correct as it is humanly possible to make them, upon the basis of facts, experience, and judgment.

Decisions involving engineering economy can best be made by:

A clear definition of the problems and conditions to be met.

An application of these facts to the problem.

A consideration of all possible alternatives determining the method and materials to be used.

Finding the cost.

Evaluating the results both direct and indirect.

Suppose that the management of a furniture factory is faced with the problem of making an addition to the factory in order to take care of incoming business from customers and that which is immediately in sight. A decision to proceed depends upon facts which can be set down accurately, and also upon intangible elements which are to be evaluated largely by judgment. The final decision to be reached is "should it be done," "to what extent," "when," and "how." In making the final decision, questions such as the following must be answered:

Policy. Is it the policy of the company to expand—should another plant be considered, perhaps more favorable as to location in relation to labor, market, and raw materials? How will the addition be financed?

Incoming business. What orders are booked and what commitments made? What volume of business can be booked during, say, the next five years?

Cost. Estimated cost of addition and equipment; alternates as to quality of structure and equipment. Are business and equipment costs going up or down? What effect will this addition have on the operating cost of the entire factory? What additional expenses will be necessary to rearrange existing equipment to make an efficient layout as a whole?

When. How long will it take to construct the addition? To buy and install equipment? To train additional labor before there will be a return on investment? Will it be wise to pay a premium for rapid completion?

How. Should the addition be designed and erected by the company's own employees, or placed in the hands of an outside engineer and contractor?

These questions and many more must be decided in order to arrive at a final decision regarding the project as a whole. Some simple questions depend upon assembling of facts, and they solve themselves; others are ones upon which factual information is quite scanty and such facts as do exist must be evaluated and the decision based on the exercise of judgment.

The capacity and cost of the addition can be closely estimated, as well as the time required for completion. However, general business conditions and the volume of incoming orders at the time of completion and for the succeeding months and years cannot be accurately foretold; they must be estimated, exercising careful judgment, and using such data as business trends, plans for number of sales people, and the past history and probable future for the demand of the particular product.

In leaving the matter of making decisions, three factors often considered in arriving at a wise conclusion should be briefly mentioned. They are "point of diminishing returns," "minimum cost point," and "break-even point."

The *point of diminishing returns* is well illustrated in the insulation of a house, where insulating materials are inserted in the walls and roof to decrease heating costs. As the amount of insulating material used increases, increased benefits are obtained in the saving of fuel, but a point is presently reached where additional insulation fails to produce an increasing saving, and thus is not economically justified.

In short, the point of diminishing returns is that point at which the benefits derived from an increase in the expense devoted to a factor of improvement fail to justify the increase—judged from total results obtained. A plant assembling small mechanical apparatus, requiring the use of many small nuts and screws, may lose much by such small parts being thrown away as scrap during the rush of production. Say that by slowing down production 1 per cent, in order to reduce waste, three times as much can be saved as is lost by the slower schedule. Slowing production 2 per cent eliminates more loss, but the saving is only equal to the loss in time. At 3 per cent reduction in production, not enough is saved through scrap-loss elimination to pay for the time

lost. Or, again, a manufacturer finds the efficiency of his workmen increases when they are given five minutes' rest every hour. Efficiency is still greater with ten minutes' rest, but the increased efficiency fails to make up for the time lost—making it a matter of diminishing returns to give the men more than about five minutes' rest per hour.

Minimum Cost Point. In the design of a structure or product, there are often various factors of design which can be changed without affecting the function of the design as a whole. When we find that combination of factors, the total cost of which is the least, we have reached what is known as the minimum cost point of the design, or that point at which we achieve our purpose for the least outlay.[6]

The use of the *break-even point* is often especially valuable when we have two alternate ways of doing something. Under one set of conditions, it may be economical to do a job one way, under other conditions, another way. But what are the conditions at which the most economical way of doing something changes from the use of one method to another? If these conditions are not known, how are we going to tell which method is better fitted to our particular case? Hence, it is important to discover, wherever there are alternate

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[6] As an example, consider the design of a particular electrical control panel. The manufacturer has, based upon quantity manufacture, certain standardized metal cabinets, switches, relays, and other accessories which are available for assembly into a complete unit.

He wishes to install a standard \$20 switch in a cabinet to be wired complete with relays and other accessories. The \$20 switch, he finds, fits a standard \$30 cabinet, but does not leave room for regular \$5 relays—two of which are required. The switch and relays, will, however, fit a \$40 cabinet, or, by using special small precision relays at \$7.50 each, the \$30 cabinet will be large enough. Regular relay mountings cost \$1 per relay while those for the smaller \$7.50 relays are \$1.50 each plus a drilling charge of 50¢ per relay. The handle for either the \$30 or the \$40 cabinet is \$2, and wiring charge \$1. Still another possibility is for him to use a \$45 cabinet with a combination one-piece unit consisting of switch and relays, total cost of which is \$27. No drilling or relay mounts are required, but the handle is \$3.50, special insulation \$2, and wiring \$1.50. What is the minimum cost combination for the required design?

Combination 1	
Small cabinet	\$30
2 special relays	15
Relay mountings	3
Relay drilling	1
Handle	2
Wiring	1
Switch	20
Total cost	\$72

Combination 2	
Large cabinet	\$40
2 regular relays	10
Relay mountings	2
Handle	2
Wiring	1
Switch	20
Total cost	\$75

Combination 3	
Cabinet	\$45
Relay and switch	27
Handle	3.50
Insulation	2
Wiring	1.50
Total cost	\$79

Thus, we see how the minimum cost point has been determined by finding the combination that will result in the lowest cost. By using the special relays, a saving is made over both alternatives.

methods of doing a job under various conditions, just what the conditions are at the point where the change of methods takes place. That point at which conditions are such that it is just as economical to do a job one way as another has become known as the break-even point, and we must know the conditions existing at that point before we can wisely choose our method. These "conditions" may be of any kind, depending upon the particular situation involved.[7]

INTANGIBLES OR "JUDGMENT FACTORS"

By this time it will be observed that planning, based upon selections and decisions, is by no means a thoroughly scientific procedure because "judgment factors" or "intangibles" are continually bobbing up, where proof is impossible. Nevertheless, if all decisions rested only upon exact data, progress would be slow or impossible.

The engineer in designing a cutting tool for a proposed machine deals with known facts regarding metals, lubricants, and pressures, but the engineer who designs an automobile body is confronted by the customers' opinions and tastes relating to form and color.

The engineer assigned to design a plant to produce a new product of given quantity and quality deals largely with known facts and experiences, yet he must consider the possibility of alterations in product, in volume output requirements, or in the class of labor available.

The sales manager who undertakes developing a sales plan is dealing largely with human characteristics both as to the acceptance and the selling of the product.

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[7] For instance, in deciding whether to build a road of bituminous mat or concrete paving, the conditions determining the break-even point would probably be traffic density and nature of traffic, since pavement stands up well under extreme traffic conditions, while bituminous mat, if subjected to traffic consisting of rapidly moving trucks and other heavy vehicles in great numbers, has a tendency to become "wavy" and rough, and to develop holes. Thus, above a certain traffic density and weight of vehicles, as shown by a survey of traffic, a paved surface would be more economical, while below this point (known as the break-even point), bituminous mat would be more economical. At the true break-even point, either type of construction should be equally economical.

On the other hand, if a power-transmission line is to be constructed in which the company is faced with putting in a cheaper line and suffering losses, or spending more initially for a line with little loss, the break-even point would be determined by the operating characteristics of the system. If the power transmitted were more than a certain amount, chances are that the higher-priced line would soon pay for itself by reducing loss, but if the power requirements are below this point, the losses may be small enough so that they may never amount to the extra expenditure necessary for the better line, and hence it is more economical to use a cheaper construction and suffer the losses.

In making plans, therefore, the more the human element is involved, the more pertinent become "judgment factors" in reaching decisions. "Judgment factors" are usually found emphasized wherever matters like the following are uppermost:

Where the question of technical developments is at stake:
When the domestic ice machine was being introduced, a manufacturer of ice-making machinery had to decide whether to spend liberally in the redesign of his machinery in order to make it more efficient.

Where the question of public demand exists:
When the gasoline-driven farm tractor was developed to the extent that it could be used in a practical way, there was considerable question whether farmers would purchase it in any quantity because of their habitual use of draft animals.

Where the volume of demand has not been established by experience, and may vary with business conditions:
This factor is confronted by almost all organizations manufacturing products or rendering services. Judgment is of vital importance in establishing manufacturing schedules, locating a new telephone exchange, or erecting a new gasoline service station.

Where natural hazards or accidental conditions may exist:
How far above previously recorded flood levels should a power plant located on a river be erected?

Where financial matters are involved:
One may have to decide whether to apply existing funds to a project in place of using them for other needs, or whether to borrow money, if funds are lacking and credit exists, to carry out a desired project.

Where public relations are involved:
The effect of an increase or decrease of power rates on the part of a public utility may well tax the judgment of the management.

Where a change in company policy is involved:
A manufacturer of equipment may have been selling his complete output through independent mill supply houses. In order to reach the market in a more adequate and economical way, he may consider establishing his own branch offices to sell to customers direct.

It will be seen that judgment factors may be of as much as or even more important than definite facts. Whether the problem involves considerations of a social, economic, financial, or physical nature, there is a likelihood that judgment factors play an important part in the solution of every engineering problem.

One condition where judgment factors or intangibles come in for a great deal of consideration is in deciding whether an alternative of an original plan would not be the proper solution of a problem. Too often, in planning an improvement or a change of some sort, not enough

attention is paid to alternate ways in which the same result can be gained and with a greater rate of return or less investment.[8]

Previous mention was made of the important break-even point in choosing between alternative ways of accomplishing something. In the example cited in footnote 8 of the railroad faced with the problem of increased tonnage and inability to handle it with existing motive power and grade conditions, the break-even point comes into play and can be determined only through the use of intangibles or judgment factors concerning future tonnage conditions. That is, the break-even point is undoubtedly determined wholly, or in part, by some set of tonnage conditions. If the increased tonnage is over a certain amount, it is quite likely that the decision reached will call for a grade-reduction program, while, if it does not reach this point, the original plans of increasing motive power may be the more economical. Thus, it is seen how very complex the whole situation becomes, since both plans are ones involving great amounts of expenditure, and hence they must

[8] An excellent example of this kind is furnished by a railroad faced with conditions of increased tonnage beyond the capacity of existing motive power. On first thought, engineers might begin to plan the purchase of heavier motive power which could handle the added tonnage. Second thought, however, brings up the alternative of a grade-reduction program to enable existing motive power to handle the extra tonnage. Judgment factors are numerous, and, if carefully considered, it may be determined that perhaps the grade reduction would so economize all operations that its extra cost over that of new motive power would be easily justified. A few of the judgment factors to consider are the immediate need for heavier rails and bridges, new roadbed, and heavier and redesigned operating and maintenance equipment in the event that heavier locomotives are purchased. It is easy to see how these rather obscure factors might tend to throw a new light on the proposal of new motive power and change the plan, instead, into one of grade reduction. (See "Principles of Engineering Economy," by E. L. Grant, Ronald Press Company, 1930, Chapter 16.)

A machinery builder sells a large machine to an important customer for \$10,000, upon which there is an estimated net profit of \$1000. The machine is to be delivered in 90 days from receipt of customer's order. At the expiration of 70 days, the machine is sufficiently complete to move to the testing floor for the purpose of making a trial run. During the move, an accident occurs, which will require 30 days to correct and at a cost of \$500 under normal shop operating conditions. By working night and day, involving overtime expense, the correction can be made within 15 days at a cost of \$750. The ultimate purchaser is very anxious to obtain the machine according to the original shipping promise. Which course should be followed in correcting the accidental defect? Obviously, the answer depends largely upon matters of judgment, because factors relating to the machinery builder's reputation, the importance of additional business from this particular source, and the intensity of the purchaser's need for the machinery according to the original delivery date are to be evaluated according to opinion before a decision is reached as to procedure. The shop cost of correcting the defect, and the consequent reduction in profit, together with the time required, are the only facts of a fixed nature to go on.

prove adequate in the years to come. And to be such, it is necessary to consider many intangibles affecting future tonnage, so that the decision will not be based entirely upon the conditions of increased tonnage, as they exist today, but upon what will exist in the future.

WILL AN INVESTMENT PAY?

Much has been said of the importance of planning an industrial undertaking, and of the favorable position of the engineer in doing this because of his habits of making decisions by a thorough analysis of facts—both real and intangible. The primary question that the engineer must answer in planning an investment or an economic undertaking is—will this undertaking pay? Just what, we might ask, constitutes a paying investment?

In general, an investment may be said to be a profitable one only if it yields a revenue which furnishes a "fair rate of return." It now becomes necessary to set a value which may be considered a "fair rate of return" and then, by careful analysis, to estimate the actual revenue or return on the investment to see if it comes up to this set value.

In setting a value for a fair return, two factors must be given consideration:

1. What is the current rate of return that is available by the investment of the funds that are anticipated for this undertaking in some other conservative place?
2. Upon what additional rate of return should our calculations be based in order to justify the uncertainties of the undertaking?

The first consideration—that of current rate of return on any other conservative investment—is easily determined as a matter of known fact. The latter rate, based upon the uncertainties of the undertaking, is more difficult and involves many intangibles. For instance, such factors as the future of the industry, competition, changing market conditions—all these have to be considered. Likewise, errors or risks which may be overlooked in the estimation of costs are uncertainties which must be considered when calculating a fair rate of return.

When a value for the current rate of interest, as well as one justifying the hazards and uncertainties of the undertaking, have been arrived at, the sum of these two represents the minimum rate of return upon which to base any calculations used to decide whether to make the investment.

Consider that an engineer is called upon to decide upon the erection of a $100,000 plant for the making of "alco-gas," a blend of alcohol

and gasoline which the organizers believe will be a better and cheaper fuel than gasoline.

The engineer first estimates the gross income from the sale of the new product from this small plant as $75,000 annually. A careful estimate of the annual expenses for this production volume, including management, labor, materials, depreciation, and all other expenses, is $54,000. This leaves an estimated return of some $21,000 on the proposed $100,000 investment. In order to justify the construction of this project, then, it is necessary to determine whether this figure is a "fair return" on the investment.

The engineer first finds that 4 per cent is the prevailing interest that may be secured at the time on a conservative investment. Next, he considers many things, including the chances for acceptance of this new product by the public, the chances for competition in price or product by the gasoline interests, chances for dissatisfaction with the product after it has been introduced and tried, continuation of availability of raw materials and anticipated prices for them—all these and many more judgment factors are carefully weighed, until finally the engineer decides that an additional 14 per cent return must be shown in the calculations to take care of all these uncertainties. Combination of the current rate of return and this figure shows that the return upon which to base decisive calculations is 18 per cent. It was shown in the estimated annual return that $21,000 would be earned on the investment. This is 21 per cent, and therefore it is agreed that this project should be undertaken and that it will, in all probability, be a paying one.

From this example, it is easy to understand the many considerations that confront engineers in planning an undertaking such as this. Other examples could be cited where both tangible and intangible factors determine whether the investment or undertaking will be a paying one. Whether it is an addition to a factory, the addition of a new product to a line, the installation of conveying equipment, a foundry, a new advertising campaign, or merely the addition of a new salesman —the question first and foremost before the decision to go ahead is made is—*will this investment pay?*

ENGINEERING REPORTS

Plans, as we have seen, are based upon the gathering and arrangement of facts, and the drawing of conclusions from these. The facts gathered, in most instances, relate not only to physical but also to economic conditions, and the conclusions to be reached are based upon

economic as well as physical principles. Since the engineering report is the common method of presenting plans, conditions, and conclusions, it is highly desirable that we clearly understand how such a report can best be prepared. In practice, most engineering reports must provide material necessary to reach a final economic conclusion.

For instance, an engineer is assigned to test a Diesel engine of modified design recently put in operation. In addition to the actual performance of the machine, its success depends largely upon various factors of cost, such as outlay for fuel, maintenance, repairs, foundations, and installation, and, unless facts of an economic character are gathered and interpreted, sound conclusions cannot be reached, because they deal with one phase of the success of a business enterprise.

The purpose of any engineering report is to outline clearly, concisely, and accurately all pertinent facts concerning a situation or problem, satisfying the purpose for which the report is prepared. Reports will, obviously, differ greatly, but those most frequently prepared fall into the categories outlined below:

> *Operating reports,* which deal with performance, over a period of time, of a piece of apparatus, a production process, a construction project, or an enterprise. Such reports deal mainly with technological and economic facts, to show the conditions and results of performance—or non-performance.
>
> *Research and experimental reports,* which deal with an exact description and interpretation of observations of a carefully planned process of research or experiment.
>
> *Design or construction reports,* which deal with the character, merits, and limitations of a proposed new or changed structure, leading to the decision to proceed, modify, or disregard suggested procedure.

Various phases of the above classification of reports may be covered by individual reports, such as reports on valuation, costs, materials used, labor necessary, or outside assistance required. Reports may be also of a preliminary nature, to present facts upon the desirability of further investigation.

No matter how long or short the report may be, he who prepares it should have clearly fixed in his mind, or on paper, the outline to be followed, establishing a logical arrangement. The writer should never strive toward a style which represents only an attractive example of expression, but rather make every effort to express briefly, with greatest clarity and simplicity, his facts and conclusions.

Engineering reports will, of necessity, differ greatly in their size and

mass of supporting evidence, no matter what the nature of the report may be.

Preparing an Engineering Report. In preparing engineering reports, *planning* is the first and most important step. Not only the report itself, but also the collection of information,[9] its study, and analysis must be carefully planned. To begin work on an engineering report without a plan or outline of what is desired, and what information is needed and where it may be found, is no less disastrous than a motor trip in unknown territory without a map. A few of the essential points to bear in mind in writing an engineering report are:

> *Arrangement.* At all times, a plan of arrangement should be carried out which will, in logical sequence, lead a reader from the statement of the problem at hand, through the facts, principles, and arguments as they are presented, to a definite conclusion.
>
> *Clearness.* The report must leave no doubt in the mind of the reader on any point.[10] This may require statement of theories and definitions of terms used.
>
> *Conviction.* A report must be such that the reader can easily examine it thoroughly, and have sufficient reason for being convinced that the conclusions are well made. A conclusion lacking conviction is worthless.
>
> *Brevity.* Although some reports on extensive projects or complicated

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[9] The four general sources of information to which an engineer may go in finding a solution to a problem are:

1. Information possessed by the engineer, himself, in his records and memory.
2. Information possessed by others in a particular field—in their records and memories. To secure and use this usually involves some form of credit.
3. Information available only by conducting analyses, tests, experiments or surveys.
4. Information available in published form relating to some particular field or profession.

[10] The importance of eliminating doubt in reports was brought forcibly home to the author on one of his first assignments with a steel company. A section of a mill was being remodeled, and, to facilitate this, great amounts of materials were put on railroad cars which were taken several miles away to a sidetrack—later to be returned as the equipment was needed. The author's job was to keep a record of what was on each car so that, when the material was needed, the car could easily be located and brought to the mill.

When the last car had moved to the siding, the author's report seemed very complete to him. Every piece of equipment and the number of the car on which it could be found were carefully recorded. The "boss" then asked for the report for use in locating equipment as needed. He looked over the rows of car numbers—then asked, "What railroads do these cars belong to?" The author had recorded none of the initials of the cars, and his report was useless. His next duty was to tramp several miles to the siding, find each car, identify the equipment—and finish his report properly.

activities may require many pages to be complete, as a rule reports should be concise and conservative of a reviewer's time and patience. Tendencies toward extensive descriptive material must be watched and checked. Efficiency is the watchword, today, even in reports.

Accurateness. An engineering report may carry a large amount of weight; hence accuracy of data, subject matter, conclusions, and interpretations cannot be overemphasized. Unless a report is frank, unbiased, and correct in the smallest detail, it is better for it to remain undelivered.

Reader's Viewpoint and Phraseology. Anticipate who the reader of a report will be, and write in his vocabulary or one he will find easy to interpret. It is never a sign of knowledge to make a report which is knowingly "over the head" of the reader.

Reader's Interest. Have a clear-cut style that is easy and enjoyable to follow. An illustration or transition phrase, it must be remembered, may clear up a doubt. Make the manuscript mechanically easy to follow, and carefully edit and revise the report before it is put in final form. Use good English.

The mechanics of making a report are relatively simple and easily adapted to most situations. Reports may be either *informal* or *formal.*

Informal reports are those not requiring extensive data and evidence, and are usually in reply to a relatively simple technical question or problem. Usually, they are written as a letter, not long, and in the first person.

Formal reports, on the other hand, require many data and much evidence to arrive at a solution to an extensive or involved engineering problem. Ordinarily, they are in the third person, and follow a somewhat standardized order of presentation, as follows:

Title page.

Preface, letters of transmittal, or foreword.

Abstract—a summation or synopsis of the findings of the report. Sometimes an abstract is entirely unnecessary.

Text of report.

Object—a clear statement of what the question or problem to be solved is, and its limits.

Definitions—often terms are used in the report which need defining or explaining to clarify their use.

Method of procedure—how the facts were developed in solving the problem.

Equipment or apparatus—if laboratory or other testing was done, or surveys made, the methods and equipment used should be brought out to establish the reliability of the findings.

Data—either the complete data or a summary thereof is given to explain the basis of findings. When the data are extensive and voluminous,

often only a summary appears, while the complete data are put in appendices at the end of the report.

Interpretation of data—when the conclusion is not obvious from the data, an analysis of the data is made to show how the solution was arrived at.

Conclusions and recommendations—that is, the solution to the problem, or the results arrived at.

Appendices—where data gathered are too extensive to include in the body of the report, each set of data is made a separate appendix and put at the end of the report.

Index—provided that the report is large enough to require it.

It can thus be seen that the engineering report is a carefully *planned* and executed program of informing others along technical and related lines, and that it must be given much care in preparation. The engineer should endeavor to make each of his reports a definite and worthwhile contribution to engineering information and literature.

REFERENCE

THOMAS R. AGG and WALTER L. FOSTER, "The Preparation of Engineering Reports," McGraw-Hill Book Company, New York, 1935.

CHAPTER III

HUMAN AND PUBLIC RELATIONS IN INDUSTRY

INTRODUCTION

The young engineer may reasonably question why he should devote a share of his study to *human relationships,* and what this has to do with a study of economic principles related to supplying engineering products and services. We have pointed out that, in the industrial world of today, accomplishment comes through groups of individuals working together, in a systematic way, toward creation of utilities, and that organized personnel is just as essential as organized equipment for the purpose of production.

If every machine which industry employs had a certain freedom of decision, as do individuals, as to what it would do, and how its work would be performed, we would find ourselves in a sorry state of affairs. Since success in industrial accomplishment depends so much upon human cooperation, and this, in turn, rests upon factors which contribute to the happiness and well-being of the individual, the successful engineer cannot escape giving intelligent study to the principles which underlie human cooperative effort. The obtaining of such cooperative effort obviously has a distinct and essential economic value.

In considering *public relationships,* the engineer in his work as a part of an economic unit finds need for better understanding of the relations that do or should exist between the organization with which he is connected and public or semi-public institutions. Furthermore, he is definitely interested in the relations that do or should exist between the organization with which he is connected, and that which we call the public itself. This is particularly true if he is employed by some form of government or publicly owned enterprise or that which we term public service, where successful relations with the public in general are overwhelmingly necessary.[1]

Considering all forms of organized institutions commonly found in this country, we find a wide variety to exist. They may be distin-

[1] Reference: "Public Relations—First in the Order of Business," *Business Week,* January 23, 1937, p. 31.

guished—aside from the nature of activity, relative size, and position—according to the following qualifications:

> Whether or not they are established for the purpose of making a profit.
>
> Whether they are privately owned, or owned by some form of government authority.
>
> The degree to which their activities are regulated by some form of government control.

The greater number of organized institutions entering into our business life are formed and operated to make a profit, though we find a large number of institutions, such as schools, hospitals, and eleemosynary organizations, formed to render a service without profit.

Ownership of a large number of our businesses and other organizations still remains in the hands of private individuals, usually as stockholders. We look upon the citizens as owning the national government and its subdivisions, although the relationship is by no means limited to this. The government also owns and operates some economic units, and the degree to which this should be extended constitutes one of the vital issues of the day.

All enterprises are regulated to some degree by government authority, or come under laws which affect their operations. Those which furnish products and services regarded as necessities are regulated more closely than others, and they are not free to restrict their services or products to those they may select to serve.

In our discussion later upon industrial organizations, we will deal largely with privately owned and operated companies, established for the purpose of profit making.

From the point of view of public relations, the privately owned and operated company is distinctly interested because good public relations have so much to do with its success as a supplier. With an increased tendency toward regulation by the national governments, which has been regarded with apprehension by those who own and operate private enterprises, the subject of public opinion has a vital meaning.

Those privately owned and operated companies which furnish what we term a public service are particularly concerned with public relations, because their business is done with a very large number of customers representing a cross section of the inhabitants of the district they serve. Also, they are to a greater extent subject to government regulation and control.

From the point of view of public service rendered directly by our national government, or its subdivisions, the matter of public relations is of obvious importance, because with our present form of government it has a distinctly political bearing.

We have, therefore, a rather complicated situation, in which privately owned enterprise has a distinct interest in public affairs:

> For the purpose of furthering the success of private enterprise as both a consumer or purchaser, and a supplier or seller.
>
> For the purpose of supporting the various forms of government—local, state, and national—under which we all operate.
>
> For the purpose of developing and preserving within an industry a situation which is conducive to stable and healthy operation.

References

"Public Relations in Industry," *American Machinist*, September 8, 1937, p. 823.

JAMES E. McCAFFREY, "Public Relations," *Journal of the American Water Works Association*, November, 1936, p. 1716.

The McGraw-Hill Publishing Company has issued an interesting and informative study in three parts, entitled "Public Relations for Industry." It appears, in part, in several McGraw-Hill technical publications, and as a whole in *Business Week*, October 1, 1938, p. 21; it is available also in reprint form.

THE NEED FOR HUMAN UNDERSTANDING

Many years ago, the engineer was looked upon as a person removed and remote from business and society. He appeared, to others, as one living in a world of technical accomplishment understood only by himself and his few professional associates. His work, contrasted to that of the lawyer, preacher, teacher, or merchant, held no close ties to the mass of society. His accomplishments were viewed with a certain awe, because people knew little about matters of a technical character, which to them were surrounded with mystery.

Since then, the accomplishments of scientific and engineering skill have, through mechanization in its various forms, gone far in changing our methods of living. People, year by year, are being more closely thrown together, and progress becomes, to an increasing degree, a matter of group accomplishment. Armies of men and women have been trained in the theories of technical accomplishment. Technical methods and the approach to problems used by the engineer are, to an increasing extent, being adopted generally. Men with an engineering training are entering a wide range of business enterprises. More and more, problems foreign to the drawing board or mathematical formula present themselves to the technical graduate as he advances,

so that today a large share of technically trained men will depend, in their successful progress, upon a knowledge and understanding of people and of matters of human relationship.[2] What becomes of vital importance to the engineer, in addition to the consideration of economic factors, is a knowledge of human factors and an understanding of the responsibilities of the engineer to society and government.

As we have pursued our regular courses of study in the fields of science and engineering, we recognize that our training and experience are largely among the exact sciences. The problems that we encounter call for a quantitative or qualitative solution. Laws are established, materials that can be weighed and measured are considered, and exact results obtained. In our experiments, we control the conditions under which they are performed. We have no difficulty in duplicating, over and over, the same scientific experiment, because we dictate and preserve those conditions under which we proceed.

In our social and economic life, this is not true. Never can we perform a social or economic experiment under exactly the same conditions, for we cannot *preserve* the same set of conditions. We continually find unexpected factors entering into the procedure which upset our plans and calculations. Although we can initiate a social or economic experiment, we have no means of stopping it once it has started. The results of such an experiment may become far-reaching, and bring about effects that are almost beyond the power of imagination. Since each one of us is a member of society and a part of our economic system, we are all affected by what occurs. Unfortunately, there has been a tendency, in recent years, to attempt to perform social and economic experiments, much as one would perform a scientific experiment, and do so on such a scale that the results may go far beyond the intent of the experimenter.

We have pointed out already that, in our rapid course of technical

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[2] Gerard Swope, President of the General Electric Company, in his address before the 59th annual meeting of the American Society of Mechanical Engineers, in December, 1938, made this statement in referring to the activities of engineers:

> In addition to the study of materials and methods, they should know the history of the industrial revolution and the organization of labor, and, basically, the working man and his aspirations. The best ways of presenting problems to the men, so as to increase their interest and good will, should become a part of the engineer's function, so the understanding of the men may be appealed to and their cooperation secured. The engineer must comprehend and make clear that the final aim of industrial organization and improved methods of production is better living standards not only for the community as a whole, but for the men who are devoting their lives to a particular industry.

progress, resulting in mechanizing what has been human effort, there have been released social forces so large that we are unable to determine how far or in what direction they will lead us.

No student of engineering and perhaps no one individual can find a satisfactory answer to our social and economic problems. Each of us, however, through a greater interest in these problems, and an approach to them in a manner analogous to the analytical approach of the trained engineer, can contribute to a solution. Such a pursuit will be more fruitful if it is based upon fact rather than fancy, and upon known laws, rather than "hunches." To approach the subject intelligently, however, we must understand better the human being and the laws which govern human relations.

FRANK B. JEWETT, "The Engineer and Trends in Economic Thought," *Electrical Engineering,* August, 1938, p. 339.

D. C. JACKSON, "The Social Significance of Engineering," *Electrical Engineering,* February, 1939, p. 59.

ORGANIZED HUMAN EFFORT

The producer of utilities is confronted with the subject of human relationships principally in two broad ways: in obtaining enthusiastic acceptance of the product produced or service rendered on the part of those purchasing and using it, and in contributing to the success and happiness of those individuals who gain all or a part of their livelihood in serving the producer, by giving them an opportunity to produce to the maximum capacity. In this chapter we shall consider the second.

The first step in organized production required the services of more than one individual, and we found a condition where two or more individuals were called upon to work together toward a common end. Two conditions came to exist: a division of work by which individuals performed different duties, and the necessity of one individual directing the efforts of another. This brought about profound changes, for, as the economic unit grew in size, the efforts of any worker became narrower in scope and nature, or, as we term it, "more highly specialized." Workers became organized into a "gang," and an individual was put in charge to direct it and develop maximum production. Thus, we had one individual saying what should be done, and a larger number doing what was assigned to them according to instructions to be followed. As the economic unit increased in size,

and groups themselves were specialized as to the kind of work done, one man could no longer direct all groups, and additional individuals were assigned to directing individual groups.[3]

If the young engineer is to take his part in successful accomplishment under our systems of providing products and services, he must gain an insight into the background of man's associations in these processes of industrial development, understand the habits of people, and gain a picture of the changed condition under which man works at the present time.

MAN'S ASSOCIATIONS

The growth of trade and industry has steadily brought people into closer daily contact with one another. Not only this, but the accomplishments of technical progress have made it possible for most people in this country to come into physical contact or communication with others easily and quickly. Years ago, the farmer's son saw few people, and his horizon of human contact was distinctly limited. It consisted largely of contact with members of the family, the farm help, local merchants, and the neighbors attending school and church. A few books and magazines, and an occasional local newspaper, were his main sources of written information. What cheap transportation and communication have done during the present century to broaden the opportunities of disseminating and receiving information are by comparison with previous centuries startling in the extreme. Industrial activity and commercial activity have gone hand in hand in creating and enlarging large centers of population. In many towns, the industrial plant is the chief business interest. Large numbers of families, businesses, and other institutions depend for their existence and prosperity upon the activity and success of these large producing units.

Since these productive units have developed and prospered through the organized and united effort of large groups of individuals, this same principle of group activity has been further inculcated in the

[3] Today, we speak of "management" and "labor" as though they were distinctly separate groups. This was true when there was one boss and a number of individuals under his immediate direction. Today, however, in our industrial system, one may well ask, "What is the management?" for almost all workers receive orders as well as give them. Most orders are functional in character. The designing engineer lays down certain rules, as does the factory inspector, accountant, or shop superintendent. Even the machine operator is a "boss" of his machine. *All workers* in our corporations today both give and receive direction, for even the president is accountable to company directors, and these in turn to the company stockholders.

people. Americans have become accustomed to working together in groups, each one with an assigned duty, and the success of the individual is continually more dependent upon his ability to cooperate with others in attaining an objective. Group activities of all sorts—educational, social, political, and recreational—serve to draw us in closer contact with one another, as well as with the business units from which we obtain our livelihood, which have constantly increased in size and number.

Such conditions as these have created a host of new situations to which the individual has been required to adapt himself if our society is to continue to exist and progress.[4]

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[4] Of interest in this respect are some of the recent economic changes in the United States as found in the "Report of President Hoover's Committee on Recent Economic Changes" of his conference on unemployment (Government Printing Office, Washington, 1929). Only a few of the many findings are enumerated:

1. In the period 1922-1929, we find a rising standard of living. There is increased participation of people as a whole in the benefits of increased productivity; hence broad social advantages of our accelerated business and industrial activity were felt throughout the land in the form of good roads, educational advantages, better transportation and communication, the radio, the automobile, etc.—all of which were widely enjoyed by almost everyone.

2. The trend shows that we worry much less about our primary requisites and that our wants are a broad list of those goods or services that come under the classification of "optional purchases" or luxuries.

3. A trend toward shorter work-week and work-day has given increased leisure both in the home and industry. This has been reflected in increased interest in fine arts and science, increased foreign travel, sales of magazines and books, sports participation, and domestic traveling. Greater school enrolment in high school and colleges as well as increased attendance of motion-picture theaters and increased ownership of radios are all results of this trend to increased leisure among the American people.

4. People cannot consume leisure unless they consume goods and services; therefore, leisure—as the result of increased man-hour productivity—helps to create new and broader markets.

5. The survey shows that wants are nearly insatiable—that a want satisfied makes way for another want. This would indicate that we have a boundless field before us and that new wants will constantly make way for newer wants, as fast as they are satisfied.

6. We are spending $2,500,000,000 on private and public education, and there has been an increase of nearly 350 per cent in little more than ten years in expenditures for free colleges and universities.

7. The period of this survey (1922-1929) has seen a broadening influence of America's creative minds—the minds of the leaders in education and government, in management, research and labor, in the press and the professions. We have come to look in great measure to their influence for maintenance of economic balance in the United States.

These few of the many findings of President Hoover's committee show how changed conditions are evident on every hand and that their effect is widespread. The trend of this change has continued to the present day.

HABITS AND THE INDIVIDUAL

At the very start, the young engineer must recognize that individuals with whom he comes in contact spring from a wide variety of environments. Each person, with individual desires, emotions, and mental equipment, presents a complexity of changing personality filled with surprise to the person coming in contact with him, as the relationship and personality develop and unfold. Characteristics appear, perhaps unseen upon initial introduction, which the interviewer classifies according to his individual standards as being "good" or "bad." Even so, mistakes of judgment are often made, in misinterpreting and misjudging reactions as they appear, and perhaps in time the standards of good and bad prove false, and must be changed. Prejudice, then, is one of our greatest avenues of weakness. Because an individual wears clothes which to us are peculiar, or pronounces a word incorrectly, or perhaps thinks carefully before he acts, giving the impression of laziness, we must not be too quick to assume that such matters betray the fundamental character of the man.

As contacts with people increase in number, one is struck first with the fact that there is a great difference between individuals. Some show honesty in every act, whereas others show deceit; some are bright and others are dull; some are pleasant—others disagreeable. As we study people and their development, however, we find that both good and bad qualities can be acquired, for all people have the capacity to learn. Learning is simply the acquisition of qualities and abilities by doing. By doing a thing in a particular way, an individual tends to do it again in the same way, and also to do it more easily and skillfully. In this way habits [5] are formed which bring performance

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[5] No attempt will be made here to analyze in detail how we "learn behavior" or form habits; these subjects are treated extensively in writings on psychology. Learning takes place through three primary processes:

The trial-and-error method—by which successful acts are selected out of a mass of random acts. For instance, consider an animal confined in a box, the door of which may be opened with a string. Food is placed outside the box, and the animal in going through a variety of motions finally opens the door by operating the string. Many random movements are involved, but on repetition these are decreased and gradually eliminated.

The learning by association—by which specific responses are attained from a given set of conditions. For instance, the child knows not to touch the stove, because he has been burnt, or not to attempt to eat the lemon because it is sour.

The development of well-coordinated behavior, or habits. For instance, in learning to swim, the arms and legs operate in any direction and the breathing has no relation to the motion of the limbs. When coordination is obtained, and performance learned, the person swims.

continually from the realm of consciousness into the realm of subconsciousness. We see the workman at the bench performing a series of repetitive operations in the assembly of small parts, with an amazing dexterity and speed due to a coordination of eyes and hands. There appears to be not the slightest direction from the mind except when some defective part presents itself and upsets the routine sequence of movements, calling upon the mind for direction in meeting this emergency. When the operator first started to learn this particular job, the mind was active, and each move was directed from the brain, but with continued repetition the lower nerve centers took charge.

In a similar way, the individual acquires habits through learning which fit him for development in his relations with other persons. Such habits as friendliness, interest in others, decisiveness, sound judgment, industry, accuracy, and initiative, together with many more, are thus formed that have a tremendous effect upon the individual's future progress. What he does, and the traits exhibited, in a strange way influence the environment under which he works. Friendliness on the part of the young engineer, for instance, when he is in contact with others of greater experience may open up for him a personal contact which serves not only as a source of information to him but also as a cause of recognition which encourages him toward further development of this particular aptitude. Invariably we find a group of men, directed by a leader, taking on the characteristics possessed by that leader. If he is pleasant, the spirit permeates the group, and they often unconsciously come to react in a similar way. If he establishes a tempo in procedure, they fall in line and adopt the gait that is set. Each minor act of his is closely watched and often followed.

Most of us develop our aptitudes in a way such as this—at first by becoming slightly interested and skilled in a particular kind of activity and then receiving some recognition of accomplishment which leads to further interest in attaining more skill—which leads to a higher degree of perfection and recognition. Habits are thus formed, just as by the skilled workman at his bench. In a peculiar way, habits are evolutionary, for they grow and become more firmly fixed, resisting change or revolution. Hence, it is important to make a choice of habits to be formed rather than allow ourselves to form them without selection and guidance. Preliminary, therefore, to developing satisfactory relationships in our contact with others is the development in ourselves of fixed habits relating to skill, knowledge, taste, judgment, and character. Possessing these, the individual, as his responsibilities increase and as he works more and more through others,

becomes better able to accomplish objectives requiring successful cooperative effort.

THE CHANGED ENVIRONMENT OF THE INDIVIDUAL

Technical development through group activity in all its phases has produced conditions wherein the environment of the individual has undergone a marked change. These changes in environment have, consequently, had their effect upon the individual.

The most obvious change in regard to employment has been a *continually increasing degree in specialization* in work performed. Mechanization of production, construction, public service, and maintenance makes it necessary that a considerable share of workers devote their time to performing the same operation or a series of operations in rapid sequence. This may be illustrated by an individual assembling the mechanism of a water meter, the parts of which, machined to definite limits, are brought to the assembly bench and placed in containers exactly in the position where they may be most quickly selected. The same series of motions is repeated over and over in the assembly job. Or, again, consider the individual operating a lathe in the forming of a given part which requires a series of motions in rapid sequence. As we have previously seen, the eye and hand operate with little or no direction from the mind, and the work can be efficiently performed with little or no knowledge beyond the immediate responsibility of the operator.[6] Whereas, years ago, the workman's duties included a wider range and greater variety of operations, and he had to make and fit parts together so that the finished product would operate satisfactorily, today his work is highly repetitious and he is under pressure to perform the same operations as many times as possible in a working day. Such production methods call for specialized effort within the entire manufacturing unit, since the duties of design, inspection, time study, stock maintenance, machine maintenance, packing, and many others have become standardized and follow a close routine.

When the mind ceases to guide the hand, it is free to devote its time to that which has no relation to the work, and thousands of thoughts can enter. Prejudices can easily be formed and grow. The

[6] When the author was taking the training course of a large electrical manufacturing company, he chanced one day to be watching the winding of coils for electrical apparatus. Observing the cotton covering on the wire, he slyly asked a machine operator what it was for. "That's funny," replied the winder, "I've been here ten years and never thought of that question."

worker's activities being highly specialized, he has less opportunity to observe and evaluate the various duties of others. With the growth of the productive unit in which he works, he becomes less able to visualize all its ramifications.[7] He sees published statements of large figures showing the volume of business done, and profits made, without understanding the necessity of all items of expense or risks incurred. Working in a narrow groove, he may acquire, without adequate cause, a warped and dissatisfied attitude toward the company employing him.

There are three main ways of meeting this situation: (1) increasing the individual's interest in the completed product and the total process of production; (2) getting the individual more familiar and more interested in the company and its success;[8] and (3) with the shortening of working hours, encouraging the individual to find opportunity for spending time, when not at work, in interesting, pleasant, and useful activities. It will readily be seen that this presents to those who manage an operating company a responsibility and also an opportunity in "human engineering." Human relationships between individuals, whether they are workers with similar duties or otherwise, become of greater importance as our productive processes increase in size and become more specialized.

Another very obvious change, already referred to, has been the *shortening of working hours* for individuals employed in shops and offices as well as for those in the construction and maintenance fields. Thus, while specialization and intensity of effort have increased, daily work is done over a shorter period and there has been a gradual decrease in the number of working days during the year.

With more time on his hands, the individual has more opportunity to do those things which have no relation to his work, and the opportunities in this direction have increased enormously. The desire for entertainment has probably increased because activities in contrast to routine work are particularly welcome, and the opportunities to travel and to see and do things that bring pleasure have become increasingly available. Through advertising, for instance, there has been brought to each individual a glowing invitation to spend and enjoy. A certain restlessness has been born in many of us, usually re-

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[7] Reference: "Taking the Mystery Out of Business," Charles R. Hook, *American Machinist*, April 6, 1938, p. 267.

[8] References: "Reports to Employees," William J. Barrett, *American Gas Journal*, December, 1938, p. 31; "Glad to Know You," Burnham Finney, *American Machinist*, November 16, 1938, p. 1008.

quiring self-expression, by the pressure of routine work where the opportunities for self-expression are limited. Many more stimuli to reaction are presented to the nervous systems of individuals of today than existed for our forefathers. One has only to drive along the street or highway, or page through a current magazine, to prove this. Our lives have speeded up, and perhaps the period of life during which we are actively a part of the industrial machine has been shortened, in spite of the fact that the span of life with modern medical care has been lengthened.

The social contacts of the individual have increased greatly with the advance of industrial production. Personal contacts beyond the scope of the family now occupy a larger share of time between work and sleep. The American people, brought up with the idea that each individual must have ample freedom, are now faced with a different kind of freedom—a freedom which consists of a much larger variety of things to do, and devices with which to do them.

The engineer trained, as we have seen, in dealing with physical principles and materials depends now, in his progress, to an increasing extent upon relations with people. We must study people and their reactions as carefully and as thoroughly as we study materials and structures, and in doing so we must remember that, though certain established principles of psychology hold both for the masses and for the reactions of the individual, there is a vast difference between one person and another.

Increased competition between individuals is another change that has come from an altering environment, following in the path of specialization and keener and more closely focused competition between economic operating units. Where a larger number of individuals are placed upon exactly similar work, and pressure is exerted to produce the maximum in a given length of time, direct comparisons between the results performed by individuals are easy to make. Furthermore, individuals working in the same plant upon different classes of work have greater opportunity to make comparisons. No wonder that, with the duties of the individual becoming more defined and the massing of working people in groups, we find them organizing themselves into trade or craft unions and industry unions in order to add weight to their desires and demands, and make them articulate.

Although there has been increased competition among individuals and among economic units, and, in a degree bred from it, we find increased *cooperation*, for the whole history of industrial development has been in a recognition of the fact that individuals must cooperate

with one another toward accomplishment. Since people accomplish ends by group organization, it is necessary to understand not only individuals, but also their actions and reactions as groups, or, in other words, we must be able to treat intelligently with the elements of mass psychology.

THE NECESSITY OF KNOWING INDIVIDUALS

We have seen that the young engineer entering industry is at once thrown into intimate contact with people. He starts by working *for* someone and *with* someone on similar or different kinds of work. As time goes on, he may advance so that someone else is working under his direction, but he continues throughout life to be required to work with others, as well as to obey and give orders.

The engineer designing a machine may be required to incorporate in it a part which will follow a certain sequence of motions and deliver a specific amount of power. After determining the cycle of operation of the part, the direction, extent, velocity, and frequency of the motion, and the amount of power to be delivered, he determines the various available methods of accomplishing this so as to meet the desired performance. Being able to view all available methods, he can evaluate among them and decide upon the most advantageous one. Here he deals with materials, masses, friction, and forces, which can be determined to a high degree of accuracy. The design complete, his work so far has been pursued largely single-handed, and in itself it has no value. The machine has been defined on paper, and in effect he has set up certain physical rules to follow in building it. The building must be done by a group of people operating according to a schedule but under human control. If human control fails in pursuing the ideas set down in the design, no results are obtained.

The dealing with human beings, such as will be necessary, is not so simple, because their make-up and their performance under a given set of circumstances cannot be exactly determined. However, with a thorough knowledge of an individual, his reaction to a given set of conditions can usually be quite accurately predicted. Some individuals apparently react without reason, and certainty exists only in the fact that their reactions are based on other factors than reason. Fortunately, we find but few of this type of individual.

To solve the problem of the mechanical design, we must have a knowledge of established physical laws and of the characteristics of materials. To solve human problems, we must be familiar with established psychological laws and also, through contact and experience,

with the characteristics and peculiarities of the individual with whom we are to deal. If these factors are available, satisfactory human relationships can usually exist.

It may seem strange to us at first why undesirable peculiarities in the individual are not recognized and corrected by him. As our knowledge of people increases, we find how frequent it is that people either do not recognize their own shortcomings, or perhaps recognize them and cannot permanently correct them. In fact, this is borne home to us in a study of ourselves, as we compare ourselves with others and endeavor to recognize our points of strength and weakness.

In industry, there are important laws upon which satisfactory human relationships can exist. To utilize them successfully requires sincerity of interest and an active imagination. Imagination is vital, because, unless one can place himself in "another person's shoes" and try to understand his point of view, problems, and desires, no successful relationship can exist. The ability to visualize the individual is as necessary to the engineer as the ability to visualize the proposed machine or structure.

These laws may be stated, just like physical laws. Fortunately many people instinctively recognize them. They represent homely ideas, but nevertheless are fundamental. The laws have to do with:

Friendly methods in dealing with people, which accomplish much more than other methods.

Recognition of the importance, rights, and opinions of other individuals.

The importance of an appeal to fairness in others.

The necessity of including, with all important instructions given, the reasons on which rules are based.

Willingness to share undesirable or difficult duties rather than leave these to others.

The admission of error and adopting of steps to correct errors that may be made.

The ability of the young engineer to promptly analyze men and to adjust himself so as to be in harmony with the individual he is dealing with—no matter how separated their stations in life—may very properly be called a part of human engineering. One of the finest examples of a master human engineer in action is taken from an incident that is told about Carl Gray, while he was president of the Union Pacific system.

Mr. Gray was on the observation platform of his private car as the train pulled through a little station without stopping. The station operator, knowing his chief was on that train, was standing outside the station and waved a friendly salute to the big boss as the train rolled through. Unfortunately, the boss had his mind focused on something else and failed at the moment to notice and return the friendly greeting. (You can imagine the chagrin and the disappointment of that employee who undoubtedly believed his chief had deliberately ignored him.) President Gray suddenly became conscious of what had happened and, calling his secretary, he dictated a letter of apology to that employee! Foolishness? No, the smartest action possible of a leader, big mentally, with a keen understanding of human nature.

Mr. Gray explained to those associates who overheard that dictation, "I wouldn't for the world have any employee of ours feel he had been deliberately ignored, for with such a feeling in his heart he would unconsciously react the same way to some patron of ours. I would never know and could never correct the damage which might accrue." "Human Engineering—Salvation of Industry," Laurin E. Hinman, *Electrical World,* January 16, 1937, p. (263) 35.

SOCIAL RESPONSIBILITIES

Up to the close of the first quarter of the present century, industry was, much of the time, without a sufficient supply of common labor. Industrial leaders urged our national government to maintain immigration laws which permitted the entrance of large quotas of people from foreign countries. Industrial leaders were anxious to hire immigrants when business conditions justified it, but assumed little responsibility for them when work failed. Comparatively little effort was made, at least until recent years, to direct their ways toward American citizenship and American standards of conduct and living. We have only to witness large industrial communities today to see the results of these conditions, and the effect of failure, in the earlier days, to realize the social results that ensued in meeting an immediate economic need. Industry is coming fast to realize that economic considerations cannot be viewed singly, for invariably social conditions are also involved.[9]

In our age of accomplishment through mechanization and the governing profit motive, management presses those responsible for design and production to reduce costs at every hand. John Smith, the designing engineer, and Tom Jones, the factory superintendent, walk into

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[9] Reference: "Social and Economic Aspects of Management," *Factory Management and Maintenance,* October, 1938, p. 58.

the boss's office and show how they have got their heads together and eliminated an operation in the manufacture of a certain product which dispenses with the services of a workman, and thereby makes a direct saving. Both men are complimented on their good work, and the saving goes into effect. But, as this move is made, no particular thought is given to its effect upon the life of a certain individual—the skilled workman who must be dropped or shifted to another class of work where his training is less useful.[10]

Such a circumstance as this may not happen often in industry today, but not many years ago it was quite general. Under our mechanized competitive system, effort, in the past, has been largely concentrated upon the elimination of labor cost, rather than upon employing, training, and preserving the worker. Society, to a degree, has revolted against such existing systems, and "human engineering" is now a most outstanding problem confronting the executive who is charged with technical production.[11]

Elizabeth Faulkner Baker, "Human Problems Created by Labor-Saving Machinery," *Mechanical Engineering,* May, 1936, p. 305.

Morris S. Viteles, "How Technological Changes Affect Employees," *Mechanical Engineering,* May, 1936, p. 302.

Edward R. Livernash, "The Industrial Worker," *Mechanical Engineering,* December, 1938, p. 954.

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[10] At the present writing, engineers in the employ of various concerns have, for a long time, been pressing every effort to develop and perfect a machine to pick cotton. When it is made available, it will be hailed as another wonderful engineering accomplishment, and the average person will probably regard it as a great blessing to society as a means of eliminating so large an amount of laborious work. What will be the economic and social effect of the adoption of such a machine upon a large number of our Southern laboring population? This is a problem we must be ready to face, for the products of invention and engineering skill which take years to evolve become available suddenly, allowing little or no time for economic and human adjustment.

[11] The directors of the Johns-Manville Corporation recently (June, 1938) elected the president of the Carnegie Foundation to its directorate. The president of this corporation, in announcing this appointment, made the following significant remarks:

> American business is today confronted not only with new social responsibilities which it must discharge, but with new concepts that profoundly alter the relationships of business to its stockholders, to its employees, the government and the general public. Determination of industrial policies . . . must more and more include not merely the strictly economic factors. . . . Your interest and long experience in human development especially qualify you to advise industry as it assumes these new and larger responsibilities.—(New York Herald Tribune, June 22, 1938.)

RELATIONSHIPS IN PRODUCTIVE UNITS

In the study of human relations as concerning economic units[12] engaged in furnishing utilities, we find that they center about relations between employer and employee, among employees themselves, and between buyer and seller. Although they involve the same principles, these principles have somewhat different applications, and therefore we will consider these three subjects separately.

Employer and Employee. When we study the development of industry, we find that almost all industrial organizations had their origin in one man or only a few men. On the walls of many a corporation president's office hangs the picture of the founder of the concern, and perhaps a picture representing the original factory which the founder built and in which he worked. In the field of technical products, the founder was generally a skilled workman himself and often an inventor. He developed an idea relating to some contrivance and set about perfecting that idea and making a product which would find a market. In the language of the day, he was not an "engineer" but a "mechanic" or "electrician" who hired a few men to work with him. He was more skilled with his hands than his helpers were, and they respected him as a clever workman. Often they shared with him the risks encountered in the business that was started, and in some instances they were taken into the business as partners. The relationship was an intimate one, and owner and workmen formed close associations as the business grew. Information relating to details of manufacture was rudimentary and largely passed from one to another by word of mouth.

As a business of this type grew, many changes took place. More hands were employed; methods of operation became systematized and duties specialized. The original founder often showed lack of ability as a manager in organizing and directing the efforts of others. With experience largely of a mechanical nature, these individual leaders

[12] In this book, we shall devote our attention to those factors of direct interest to the economic units in the general field of industry. However, very vital and pointed criticism has been directed at our industrial leaders in the past, owing to the fact that they have taken so little interest in the results to society of the industrial operations which they have directed. For instance, we can find many examples of industrial plants which have been established and have grown, but have given little consideration to the interests of those living in the community or adjoining communities. Streams and rivers have been polluted, smoke and dirt nuisances have been created, and breeding places for squalor and crime have been unintentionally encouraged. Such criticisms cannot be justly directed against all companies. This phase of responsibility on the part of industry comes within the scope of the study of social sciences.

often lacked ability to handle the financial end of the business, for inventive genius and business genius seldom go hand in hand.

What interests us here, particularly, is the fact that, under these conditions of growth, those who directed the business became further removed from those who performed the manual work. Shop superintendents, and later group foremen, became necessary, and the distance between those who owned and managed the business and the workmen themselves became constantly greater. Information and instruction became matters of record handed down from one to another, rather than oral, and human contact became less frequent and intimate. Perhaps there was a change in ownership and new faces appeared to direct affairs without knowledge of individuals, much less an interest in them.

With the adoption of the corporate form of organizations, lines were more closely drawn between management and labor, and the gulf between the two became more pronounced. Labor came to be treated much as a commodity—bought as needed, and dispensed with when not required. In many manufacturing companies, where the labor market was plentiful, there was a great labor turnover, and nothing in particular was done to retain an individual if he could be easily replaced.

The training of employees was of a limited sort; the method usually followed was to place a young man under the direction of an older experienced employee. His progress, under such circumstances, depended upon the individual under whose guidance he was placed. Often the attitude of the experienced worker, who had gone through a hard struggle in his earlier days, was one of great superiority, and the younger man was given to understand that he, too, should go through a similar struggle, and assistance and encouragement should be given to him in his work very sparingly. Usually, "the tricks of the trade" were cherished by many of the older workmen, and there existed a feeling that, if they divulged them, the younger man might excel, and put the older man out of a job. The boss was often feared because the right to "fire" and "hire" rested in his hands. Favoritism was often exercised, and a constant fear of losing the job prevailed. These conditions did not exist in all factories, mines, mills, and construction gangs, but they were altogether too prevalent and they represented the spirit of the times.

Gradually conditions altered, and early in the present century these changes became more noticeable, for, with the greater specialization of effort and the introduction of mass production methods, adjustments between management and labor had to come. Labor became

better organized and more insistent in its demands for higher wages, shorter hours, and better working conditions. Management became wiser and less selfish, and began to learn labor's point of view. With management closely associated with capital, and the amount of capital required becoming greater because of increasing mechanization, management began also to appreciate that, without labor, losses due to idleness multiplied. Management began to devise ways and means of making labor better satisfied,[13] and to do so management had to gain a better understanding of the point of view of the laboring man.

During this same period the variety of kinds of work increased, and in the larger companies large armies of factory clerks, accountants, and office help developed which constituted what has been termed "the white-collar class," which, likewise, had to be dealt with intelligently.

The most important problem which management[14] had to solve was that of making the factory, mill, and mine a pleasant place in which to work, so that employees enjoyed work rather than dreaded it, and liked, rather than disliked, those who directed operations. This led to changes in a thousand ways, not only in the physical surroundings within factory walls, but also in opportunities for progress and security of employment. The problem is by no means solved, but there is ample evidence that over a period of time progressive steps are being taken for a better understanding[15] between management and labor, and more sensible methods of procedure are being adopted.[16] Fundamentally, progress has been due to the development of closer personal relationships between the individual who follows a given task, and those who set these tasks and direct the worker's efforts.

Under conditions such as these, the federal and sometimes the state governments have taken a hand in the matter of relationships between employer and employee. Legislation has been passed establishing pension systems, workmen's compensation, limited working hours, and regulations concerning safety for the employee.

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[13] Vacations help to keep workers satisfied. As of June, 1937, out of 9,570,100 persons employed in the manufacturing, extractive, and laundry industries, 36.7 per cent were working under vacation plans. In a government survey covering 700,000 *salaried* employees in industrial establishments, it was shown that 95 per cent worked in plants that gave them vacations with full pay.

[14] Reference: "New Emphasis in Management," Lillian M. Gilbreth, *Mechanical Engineering,* May, 1938, p. 403.

[15] References: "Concurrent Interest, a Philosophy of Industrial Relations," E. W. Kempton, *Power,* November, 1938, p. 78 (616); "Why We Report to Our Employees," Edgar Monsanto Queeny, *Chemical & Metallurgical Engineering,* December, 1938, p. 678.

[16] Reference: "Men, Management and the Future," F. A. Magoun, *Mechanical Engineering,* July, 1937, p. 515.

What intelligent workmen desire, above all else, are these things: [17]

Reasonable working hours.
A fair wage scale, and a share in profits.
Healthful conditions in which to work.
Safe conditions under which to work.
Opportunities for advancement.
Security [18] and stability in employment to those who are honest and capable.
Security against total loss of income due to partial or total incapacity.
Security for old age.

What intelligent management desires is that employees be intelligent, reliable, alert, capable, and industrious. Our leading operating units in this country agree with what labor desires as indicated above, but serious difficulties have arisen in reaching an agreement as to what is "reasonable" and "fair." Several companies have evolved a form of profit sharing with employees, but no single plan has been outstanding, and sufficient time has not elapsed to prove the permanent worth of any profit-sharing system. Management's most difficult problem in the treatment of labor is caused by frequent and wide fluctuations in business activity.

In recent years, the management of many corporations has realized the importance of human relations, or, as they are more commonly termed, "industrial relations" or "personnel activities." [19] Frequently, this work is regarded as of such importance that an officer of the company and his staff devote their entire time to it. Such activities concern:

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[17] Reference: "Why I Like to Work for My Company," Walter J. Held, *National Petroleum News,* July 28, 1937, p. 20.

[18] References: "And Now—Secured Incomes," *Factory Management and Maintenance,* December, 1938, p. 33; "The Balancing of Incentive and Security," Ralph E. Flanders, *Electrical Engineering,* February, 1939, p. 67; "Management's Responsibilities to Society," A. W. Robertson, *Electrical Engineering,* February, 1939, p. 81. Mr. Robertson says:

> There is a general belief that management will not hire people over 45 years of age. This is pure myth. Well-established factories with which I am familiar have a higher percentage of their employees between the ages of 45 and 68 than the whole population of the United States has between these ages. This is also true if you take for comparison ages 40 to 68, or 50 to 68. Every organization values its trained and dependable older men and, in times of depression, keeps them to the last. Competent older men always have whatever work there is.

[19] Reference: "Personnel Practices"—abstracted from Study 233, entitled "Personnel Practices Governing Factory and Office Administration," published by National Industrial Conference Board, Inc., 247 Park Avenue, New York City, March, 1937. See *American Machinist,* August 11, 1937, p. 722.

A system for the intelligent selection of employees.

A system for the training of employees toward their progress in the company's business.

Relationships with employees' organizations, both local and national.

Developing and administering a system by which problems arising between the company and the individual may be studied and, if possible, solved.

The establishing of pension systems, death benefits, savings accounts, group insurance, and similar provisions.

Carrying on plans devised to assist employees in selecting living quarters, buying homes, and conducting their affairs on a more business-like and stable basis.

Providing for adequate protection against accident, giving medical aid, and improving the health of workers.

The rewarding of new ideas applying to the particular business unit.[20]

How far management should go in helping the individual in a solution of his business and personal problems is a much-debated question. Paternalism on the part of management has its drawbacks, for it tends to discourage the employee in managing his own affairs and providing for his safety and security in the future. Many executives still feel that the best plan is to concern themselves only with the plant and working conditions, allowing the individual to develop for himself the initiative required in conducting his own affairs.

In addition to the relationship existing between the individual employer and the individual employee, if the engineer is to progress, he must understand the fundamental factors involved in connection with the activities both of employers as a group, and of the employees as a group. The subject of organized labor, hence, is one requiring extremely intelligent study.

Problems in organized labor are not new. They reach back to the first appearance of the wage earner in England, as early as 1300. At that time, copper and iron smiths, carpenters, weavers, shoemakers, and many other classes of artisans formed "guilds" in which they worked and which were often influential and oppressive to the expansion and development of industry. Around 1700, we find the first records of "unions" of any degree of permanency. Troubles among English wage earners had arisen which led to controversy, appeals to Parliament, strikes, and to the formation of "associations," "trade clubs," "trade societies," "institutions," or "unions," as they were then called.

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[20] Reference: "Securing Results from a Suggestion Plan," Hilton E. Wright, *American Machinist*, August 11, 1937, p. 692.

In 1799, the General Act of Restriction was passed, however, which declared all combinations illegal. This put employees at the mercy of their employers, but nevertheless the act stood until 1825, at which time agitation forced Parliament to pass an act giving workers explicit rights to bargain collectively for better wages and labor conditions.

In America, this same conflict was repeated, and statutes were enacted regulating wages and providing for punishment to those refusing to continue to work for customary wages. Until the War of 1812, colonial influences were seen in labor dealings—remnants of guild organizations and other English influences. However, some trade associations were organized.

Between the War of 1812 and the Civil War came the start of our factory system and aggregation of capital—and with this our present-day labor problems began. In 1827, the first trade union started—the "Mechanics' Union of Trade Associations" of Philadelphia. Strikes began to be prominent, and trade unions extended to include larger groups of employees. Wages, hours, and the "closed shop" were topics of the day, just as they are now.

After the Civil War came the period when industry and likewise the labor organizations were centralized into larger units. Local labor organizations formed into central bodies, then into state federations, and finally into national organizations.

Our first major national labor organization was the "Knights of Labor," which became national in scale in 1878. By 1886, its membership had risen to 700,000, but it then began to steadily fall off owing to expensive strike failures, political activities, and too great a concentration of power in the hands of the organization's general officers.

Our second national labor organization started as the "Federation of Organized Trade and Labor Unions of the United States and Canada" in 1881. In 1886, it became the "American Federation of Labor,"[21] under which name it stands today. Whereas individuals were members of the Knights of Labor, the American Federation of Labor was composed of unions. So long as dues were paid, representation and votes were allowed any association.

The Knights of Labor based its organization on the principle of common interest to *all laborers*; the American Federation of Labor catered to the interests of *trade* or *craft*. Now, of recent origin, is a third form—"the industrial union"—a union of *workmen in a particu-*

[21] Membership in the A. F. of L., as of August, 1938, was 3,623,000, as compared with 548,000 in 1900.

lar industry. This organization is the modern Committee for Industrial Organization,[22] and is the outcome of the resignation of one John L. Lewis as vice-president of the American Federation of Labor in 1935, after which he embarked as leader of the new industrial organization movement. And so we have, more recently, two major forms of labor organization, one organized cross-sectionally upon the various classes of skilled workers appearing in various industries, and the other vertically including all workers in a given industry. The first contemplates organization on the basis of the class of work done, and the second, on the industry of which the worker is a part. Antagonism has existed between these two kinds of organization, but it is natural that, with a change in our organized methods of production, the workman's trade has become less a pivotal point in organization than the company of which he forms a part as a workman. Labor organization has been in a state of flux, just as have been the organizations of economic units we call "companies," for there has been a continual shifting of the relationship between the industrial organization and the worker.

A program of educating the individual so that he better understands both his own and his employer's problems will do much to relieve present-day strife, and many employers can well increase their knowledge concerning the ambitions and heartaches and living conditions of their employees. With propaganda from both sides clashing, education in a rational form has not yet progressed sufficiently far.

The desirability of some form of organized labor is established; this is now acknowledged by intelligent management. Management and labor have drifted farther apart, as we have seen, but within recent years there is ample evidence that it is possible to draw the two closer together. Labor must be shown what problems face management in preserving a steady source of income to the worker. Management, on the other hand, must be shown what faces labor when employment is unstable and working conditions unsatisfactory.

That an attempt is being made to protect labor against unfair practices of management—and in a measure to protect management from unreasonableness on the part of labor—is seen in present-day legislation, both federal and state. Laws have been made to give employees the right to organize, authorities have been set up to settle labor disputes, and more recently minimum wages and maximum hours for work have been established. Differences of opinion still exist, and we are

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[22] In 1938, at the first constitutional convention of the C. I. O. in Pittsburgh, President John L. Lewis claimed a membership exceeding 4,000,000.

passing through a stage when opinions are slowly crystallizing. There is hope that from these differences will come a sound philosophy and an established system of regulations which will protect the rights of both employer and employee, and prevent the possibility of either strike or lockout.

Since the effort of the individual has constantly become more highly specialized, and most employees become attached to a particular company more closely than to a trade, the "job," as such, has constantly a greater significance. In fact, it has taken on many of the attributes of property. Progress toward a more stable industrial society, and the establishing of more mature legislation, will come only through further exhaustive study and a spirit of greater tolerance and understanding.

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Relations among Employees. It has been said that nothing shows what the individual is made of better than the hardship of primitive camp life, because there many of the formalities of our lives are discarded and we live without the man-made aids of civilization. In a somewhat similar way, the rigors of the modern factory, with the variety of individuals involved, present to the worker coming in contact with them a test of his understanding of human nature. We find on one hand those who are bored by the dreariness of routine, and on the other those who must operate under the strain of rapidly changing impressions. A similar situation also exists in any important construction job, in the mine, on the railroad, and in the public utility. Such conditions call for an understanding of human nature and also an abiding faith in it.

Aside from home ties, friends are the most valuable connection an individual has, and happy personal relationships in work create attractive surroundings more than furnishings and fixtures. The ability of the individual to make and keep friendships constitutes a great source of happiness and is a powerful instrument toward material progress and success. We see example after example of men who possess an exhaustive knowledge of the subject and never-ending energy in that at which they are working—but who sooner or later fail because they disregard the rights and the personal characteristics of those with whom they come in contact, attempting only to achieve their personal ends.

We find, repeatedly, comments such as those shown below on the personal record cards maintained by leading companies who operate personnel departments. The comments tell their own story:

> "Possesses a superior attitude toward associates."
>
> "Loses temper—lacks patience—has had several 'run ins' with other employees."
>
> "Inclined to go over the heads of fellow workers."
>
> "Shows unpleasantness at times—inclined to be 'grouchy.'"
>
> "An excellent cooperator."

Such comments as these, it will be noted, have nothing to do with the skill or technical ability of the individual, but rather with his ability to work with others.

Relations between Buyers and Sellers. In economic units furnishing a product or service, we find two activities of major importance from the viewpoint of public contact—the buying organization which deals with suppliers, and the selling organization which deals with customers. Unless close and friendly relations exist with suppliers,

stable and desirable sources of supply cannot be maintained. Sales outlets and customers, so vitally essential to any business, can be obtained and retained only through personal contact. These relationships, though of a business nature, depend for their success upon satisfactory and stable personal relationships, as we shall see in our study of distribution.

PUBLIC SERVICE

Under the heading "public service" we have come to include those services which are required by almost every citizen in conducting his daily affairs. They must be available at all times according to his needs. Many manufactured or processed goods, and other forms of service—such as amusements, milk supply, coal, fuel, or oil, which are continually being used by a larger number of people as civilization advances—approach closely to the group of necessities constituting "public service."

The furnishing of certain educational facilities, police and fire protection, carrying of the mails, furnishing water and sewage disposal, and some other forms of service are wholly or largely performed by some form of governmental authority.

The following forms of service, however, are still largely or entirely furnished by companies that are privately owned and operated, under increasingly strict governmental regulation:

Communication—telephone, telegraph, radio.
Transportation—local, intrastate, interstate.
Gas—originally used for light; now mostly for heat.
Electricity—for light and power.
Steam—to a limited extent in local congested areas for heat and power.

Some forms of transportation, such as local service provided by street cars, trolleys, and gas buses, must meet local operating conditions. This form of service is often provided by the municipality itself, or by privately owned and operated companies which receive exclusive or limited rights extending usually over a definite period of time granted by the local government in the form of a franchise. One privately owned company may own and operate a number of systems in various separated communities. Trolley-car systems, being large purchasers of electric current, are often a part or closely associated with those companies which furnish electricity.

Other forms of transportation, such as the steam or interurban electric lines, navigation systems, air lines and long-distance bus

lines, operate between a group of cities doing an intrastate—and often interstate—business. Thus, they interest a group of communities and large districts of the country.

Communication by telephone was originally a local service, but under wise private management remarkable progress was made in extending its usefulness without limits of space. Telegraph, on the other hand, in its early development was soon able to accomplish long-distance communication.

Electric power companies originally came into existence locally, to supply light and power to cities. Many of them were established and operated by the governments of local municipalities. As progress was made in the safe, reliable, and cheap transmission and distribution of electricity and in providing current-consuming apparatus and devices, privately owned and operated companies arose which established large systems of generation and distribution, undertaking service to a large number of purchasers living in scattered centers.

The question whether all these forms of public service can better be rendered directly by the government or by private companies continues to be an unsettled question over which much controversy exists.

In connection with public services such as communication (telephone), gas, and electricity, which are rendered very largely at the present time by privately owned and operated companies, we find a set of conditions that are distinctive.

> Such services necessitate elaborate and expensive distribution systems, requiring a physical connection to the premises of each individual user.
>
> Large investments are required at concentrated places for providing a source of the service.
>
> Service must be available at all times,[23] whether the subscriber uses it or not.
>
> Service must be measured and a charge made in a fair and equitable manner to all subscribers.

Whereas the individual may choose from whom he will purchase his milk or laundry service, for several sources of supply may be available, in the forms of public service considered here he has no such choice. By the nature of the service, if it is to be efficiently rendered in relation to capital outlay and operating expenses, the supplier exists as a monopoly, being the only source of service. Exclusive rights are obtained from governmental units for rendering service, which we commonly call *franchises*.

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[23] "New England Gas Companies Maintain Service through Hurricane and Flood," Alfred I. Phillips, *American Gas Journal*, October, 1938, p. 13.

With such forms of monopoly existent, we find the possibility and sometimes the tendency for certain abuses to exist. The subscriber, having no choice about the concern from which he will purchase the service, may regard the supplier as having an undue advantage over him in monopolistic control. The supplier, having no direct competitor and often being in a position where he can exercise political control if he so desires, may attempt to advance his interests to the detriment of the subscriber. Furthermore, by various devices in capital structure whereby the pyramiding of ownership has in the past made possible the control of vast interests by a few individuals, the interests of many have been made subservient to the interests of a few. The authority of government has assumed certain control over such suppliers, by which their service obligations and service charges are regulated. Progressively, from year to year, the quality of service has generally improved, its use has been extended, its cost and selling price reduced, and the degree to which government regulation [24] has been made effective has increased.

When the purchaser has delivered to his door a quart bottle of milk for a certain price, he knows with reasonable accuracy what he gets, and most people visualize what is necessary in connection with its production and distribution. If he purchases two quarts of milk, he pays twice the price of one. Not so with electricity, for it is distributed to him in kilowatt-hours, which he has difficulty in understanding, and the price varies with the amount he uses. Perhaps he moves from one location to another, and encounters a different price structure from another supplier—which further baffles him. Again, special rates may exist for certain current-consuming devices, such as ranges or water heaters. The industrial user of power meets with further rate complications depending on the time of day or night at which power is taken, or the maximum demand called for at any one time. Power factor may be a determining point in the rate. "Rate structure," as it is termed, for the forms of public service therefore exists as a complicated problem requiring an approach from the point of view of the engineer—with a thorough knowledge of the fundamentals constituting satisfactory public relations.[25]

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[24] Reference: "Federal Regulation of Natural Gas Pipe Lines," C. Emery Troxel, *American Gas Journal*, October, 1938, p. 23.

[25] Reference: "Human Engineering—Salvation of Industry," Laurin E. Hinman, *Electrical World*, January 16, 1937, p. (263) 35. This is a splendid discussion of human engineering as applied to all industry.

GOVERNMENT AND INDUSTRY

No subject relating to the broader aspects of business life is of greater importance to the engineer entering industry than the relationship between government and industry itself. With this relationship changing rapidly, based as it is upon changing conditions largely resultant from an increasingly mechanized society and a greater realization on the part of industry of its social obligations, our national and state legislatures are passing laws which not many years ago would have appeared quite revolutionary in character. Current literature [26] deals with these changes, so that our consideration of this subject will relate largely to fundamental principles which appear to be guiding our society in the laws that are passed by our state assemblies and particularly by our national legislature. We look upon these changed ideas as coming suddenly upon us.[27] On the contrary,

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[26] Dorothy Thompson, the noted columnist, recently made the following remarks in discussing governmental plans promulgated by the governor of one of our progressive states. These remarks are illuminating from the viewpoint of economic changes:

> He recognizes the fundamental fact of the stage of economic development in which we now are: namely, that industry and technique have run miles and generations ahead of finance. Industry and technique have created a new earth; they have pulled down fire from heaven; their ingenuity is breathtaking; they have set tons of steel swimming through the air; they have harnessed unseen waves of ether to make a voice and a song travel as fast as light from one end of the world to the other; they have turned beans into automobile bodies and air into fertilizers and acetylene gas into wood substitutes and wood into velvet—thereby destroying one set of economic values and creating others, all at the same time, and with upsetting speed, while finance has shown no similar imagination or ingenuity, and probably least of all in this country.
>
> He sees that the essential problem is to make capital work, to imbue it with a new enterprising spirit, and he knows that new social and financial inventions are needed for that.
>
> He also knows that what is no longer permissible in this world is revolution. He knows that the class struggle leading toward revolution is not allowed. It is not permissible, because the society in which we live is so interdependent and complicated, that under revolution, or even the breakdown for a few hours of the highly complicated mechanism, millions of people would perish.
>
> He knows that the theory of over-production is stark nonsense. Certainly there is over-production of certain commodities, simply because the more economic production of other commodities to take their place, or changes in habits of living, or new forms of world organization affecting international markets, drive them into obsolescence. But the frontiers for horizontal expansion, the social and economic frontiers, are not only not yet exhausted, they are not even visible yet to the imaginative eye.—(New York Herald Tribune, May 2, 1938.)

[27] In 1830, during the serious depression in Great Britain, Macaulay, the famous British historian, published an essay in the *Edinburgh Review*. A small part of it follows:

> If we were to prophesy that in the year 1930, a population of 5 millions,

they have been going on for many years, but find their greatest opportunity for expression in legislative action when periods of depressed business occur. Forced idleness on the part of a large share of our population which is ordinarily employed causes surges of popular action—often supported by immature thought and guided to a large degree by mass emotion.

Considering governmental authority objectively, the activities of the government that interest the engineer most in his daily work are such matters as *taxation* to support the functions of government, the *protection* of the citizen in his occupational work, *assistance* to and *regulation* of industry, and *conditions* of the worker. These matters we are inclined to treat from the viewpoint of the particular interests of the individual economic unit from which we derive our living and the particular community of which we are a part. We will discuss briefly each of these governmental activities, except the conditions of the worker, which are given attention elsewhere in the book.

Reference

"Richberg Says We Need Workable Laws," *American Business*, March, 1937, p. 16.

Taxation. Taxation is a matter that affects every individual in this country, but especially does it involve those engaged in some form of industrial activity. It has two principal objects in view: [28] the raising of revenue by which all activities of all divisions of government are supported; and the control of social affairs. No one will question the propriety of taxation for the purpose of supporting governmental activities, though opinions may differ as to the extent of such activities.

When it comes to taxation for the purpose of social control, it appears that a greater field for argument exists. Its objects in this

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better fed, clad and lodged than the English of our time, will cover these islands . . . that machines, constructed on principles yet undiscovered, will be in every house—that there will be no highways but railroads, no travelling but by steam—that our debt, vast as it seems to us, will appear to our great-grandchildren a trifling encumbrance, which might easily be paid off in a year or two—many people would think us insane. . . .

Hence, it is, that though, in every age, everybody knows that up to his own time progressive improvement has been taking place, nobody seems to reckon on any improvement during the next generation.

We cannot absolutely prove that those are in error who tell us that society has reached the turning point—that we have seen our best days. But so said all who came before us, and with just as much apparent reason.—From "Today's Opportunity for the Young Engineer," W. H. Harrison, *Electrical Engineering*, June, 1938, p. 257.

[28] Reference: "Some Challenging Tax Questions," Floyd E. Armstrong, *Mechanical Engineering*, November, 1938, p. 844.

direction affect the distribution of income and wealth, as illustrated in existing income and inheritance taxes; in financing some form of subsidy to certain classes of industries or groups of producers; and taking possession of gains which may be considered socially undesirable, as the excess-profits taxes do.

With the tendency toward regimentation and socialization in our industrial life under government leadership, the expenses of government have steadily increased. To meet this, the elements of our nation which constitute production and distribution have had to meet larger tax rates, and taxation applied in an increasing variety of ways. A tax structure rapidly changing and continually becoming more complex—requiring interpretation and the setting up of more comprehensive accounting systems and methods [29]—has, in itself, created new operating costs which must be met by the producers, distributors, and consumers.

A large variety of taxes is encountered by the producer, the most important of which are:

> Taxes on property, such as land and buildings, to be paid to the city, county and state.
>
> Taxes on transactions, such as duties applied to import and export shipments, and sales taxes applying to sales made in certain states.
>
> Taxes applying to the wages and salaries of all employees, such as those levied by the national government in accordance with the Security Act to provide for old-age pensions.
>
> Taxes upon profits made by the concern according to periodic financial statements.
>
> Taxes upon inventories carried—for instance, taxes levied by the state upon warehouse stocks.
>
> Taxes upon capital, irrespective of profits or losses.

Viewed objectively, the producer at once asks, "What good do these taxes do to help make a profit upon the individual enterprise in which I am interested?" Since the answer to this is usually "They have little or no immediate value," we must go beyond the confines of the individual industry or business and consider the broader responsibilities of the industry.

The engineer's viewpoint, as he accepts business responsibility, therefore, must include a clearer understanding of what should be the purpose of taxation, a study of the present methods with a view

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[29] Reference: "Wrestling with the Social Security Act," Hanns Gramm, *American Machinist*, September 8, 1937, p. 774.

to simplification, and a greater appreciation of the social responsibilities of industry.

Protection of the Citizen. We have seen that technical products require machinery, equipment, processes, and workmen in their production. In their application, use, and maintenance, they often require engineering skill, since they are frequently used by many who are without knowledge of the theory or construction of the apparatus. The safety and health of all citizens, wherever they may be, must be protected. Uniform rules must be set up by national bodies directly or indirectly under government control which will protect alike both those who produce[30] and those who use technical products.[31]

The engineer in his work must not only understand what rules exist, but must also contribute to the perfection and extension of these rules and their enforcement. To assist in building effective and fair codes of authority, the engineer is performing a valuable service in protecting life and limb, and also providing products and services that satisfy human wants in the best way.

Regulation of Industry. When industry was in the pioneering stage, few rules beyond the ethical standards of the day governed the action of industrial leaders. As a result, we find many instances where the interests of a large number were sacrificed to the interests of a very few. Many of the resources of the nation were exploited by individuals, and the savings of those less intelligent and aggressive were dissipated. As the result of such privileges and practices be-

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[30] There are many examples of what has been done to protect the worker, such as legislation regulating hours and working conditions, and requirements for safety devices on machines. The workmen's compensation acts are important in this respect. They have been especially difficult to formulate and execute, particularly since, except for employees in the service of the United States government, interstate or foreign commerce, or navigation, the United States has no authority to legislate on workmen's compensation, such action being reserved for the states. This has made things difficult since legislation had little uniformity in any two states. However, at present, states have very complete workmen's compensation laws that provide payment of compensation for injuries received while on duty, according to a fixed schedule, set up for the particular industry and injury. Whether such laws are compulsory to both employer and employee depends upon several factors and differs in the various states. The engineer should be effective both in the framing and the execution of such compensation laws.

[31] The many laws and regulations regarding construction and operation of technical equipment are all designed to protect the user. The elevator you ride in is inspected regularly; the wiring in your home is to a standard which prevents any chance of fire or bodily harm because of defective materials or workmanship. Practically every technical product or service we use today has the stamp of approval of some law or some group of inspectors.

came evident, and as higher standards of business ethics developed, the public generally became aroused and opposition grew. "Big business" became less popular, and the "monopoly" and "trust" were targets of attack.[32] This action followed two general lines:

1. Legislation aimed at those attempting to control the whole or entire activity of industries or the needs of large groups of people.
2. Legislation aimed at unfair trade practices, business favoritism, rebates, and the like.

That legislation of this kind is relatively new is not true, for it was many years ago that the first agitation for such legislation began —in fact, more than fifty-five years have elapsed. Our very rapid growth industrially in the period from 1880 to 1890 saw capital being concentrated in the hands of fewer and fewer establishments. And with this trend, each year saw increasing protest against monopoly in the control of industry. But Congress was not anxious to do anything to curb the trusts, for at the time political campaign funds were being heavily augmented by "big business." In fact, over a dozen states passed their own acts against the trusts before Congress finally was moved by popular demand to go into action.

On July 2, 1890, Congress passed the Sherman Anti-Trust Act. This was the first national legislation of this kind. The act provided that "every contract, combination in the form of a trust or otherwise, or conspiracy in restraint of trade among the several states or with foreign nations" was illegal. Infraction of this law carried a fine of some $5000 or a year of imprisonment or both. It is interesting to note, however, that this law was really almost useless since clever corporation lawyers were able to interpret such words as "conspiracy," "combination," "trade," and "restraint" so that the law provided no great obstacle to their proposed trust. History tells us that, during the period from the Civil War to the enactment of this act, but *24 trusts* were formed. The next decade after the passage of the act saw the formation of *157 trusts*.

The next important legislation against such trusts and monopolies came during the Wilson administration when, on September 20, 1914, Congress established the Federal Trade Commission. This commission consists of five members who are appointed by the President of the United States to serve a period of seven years. As the Interstate Commerce Commission has control over the railroads, the Federal

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[32] Reference: "Industry Organization and the Role of Government," J. D. A. Morrow, *Journal of Business of the University of Chicago,* April, 1938, p. 25.

Trade Commission has power to investigate and regulate the behavior of business. Actually, the commission had as its main purpose to help "big business" to abide by the law rather than to punish it for disobeying laws, even though the commission does have the power to demand reports of corporations and to publish such information as it feels should be known by the public. Likewise, it can order a corporation to stop illegal practices and can even apply to the federal district court for an injunction against a corporation. Big business ordinarily appreciates this attitude. The commission constitutes a body of experts who, by advice and warning, prevent well-intentioned corporations from overstepping their bounds and hence keeps them out of the federal courts.

At the same time as the establishment of the Federal Trade Commission, the Clayton Act was passed (October 15, 1914), which was intended to make more specific the wording of the old Sherman Anti-Trust Act of 1890. Among the things which it did were:

> Defined many illegal and tyrannical practices such as price cutting to eliminate competition, bribing of rival's employees, forcing customers to trade exclusively with a particular company, and floating bogus companies.
>
> Forbade "interlocking directorates" (in which a small group of capitalists, serving as directors of banks, oil and steel companies, and so on, controlled the business and credit of the country).
>
> Had provisions in favor of the farmers and organized labor.

One of the more recent pieces of legislation of this kind is the Robinson-Patman Price Discrimination Chain Store Act passed on June 19, 1936. Some of the provisions of this act were to make it illegal for any person engaged in commerce to discriminate in price between different purchasers of commodities of like grade and quality; to pay or grant or receive or accept any commission or other compensation except for the services rendered in connection with the sale or purchase of goods, ware, or merchandise; or to discriminate in favor of one person against another purchaser or purchasers of a commodity that is bought for resale, by furnishing or contributing to the furnishing of any services or any facilities connected with the processing, handling, sale, or offering for sale of such commodity, under terms not accorded to all purchasers on proportionately equal terms.

The legislation that has been discussed represents the more important anti-trust laws, although others have been enacted. For instance,

June 16, 1933, public law 67 was passed, known as the National Industrial Recovery Act,[33] which was designed to encourage fair competition, among other things. This was later declared unconstitutional. Still another example is public law 416 of June 19, 1934, an extract from the Communications Act of 1934, which dealt with the application of anti-trust laws and preservation of competition in commerce—relating to the regulation of interstate and foreign communications by wire and radio.

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[33] This is briefly discussed in Chapter XVI, page 389.

CHAPTER IV

INDUSTRIAL ORGANIZATION

PROFIT MOTIVE

Our economic history follows the advance which has taken place over many centuries, from the time when the individual was dependent upon his native environment for his needs to the present time when the environment is largely controlled. The sustaining of the body and its protection came as the first steps to the development of ownership of personal property, such as tools, weapons, clothing, and ornaments. Handicraft developed an increasing degree of specialization in the creation of products and services. With specialization of effort came a condition wherein the creator of a particular article of personal property found that he created more than he, himself, could use, and failed to create through lack of time or skill other articles which he required. Thus trade developed, based upon an exchange of goods through the invention and use of currency, and not only a desire to purchase, but also a desire to exchange or sell, existed.

During the seventeenth century, handicraft economy, wherein the individual or a small group of individuals working together created specialized goods, reached its maximum advance. During the eighteenth century came the Industrial Revolution. Personal wealth up to this time had existed largely in the form of land, buildings, cattle, and money. Those with money were glad to lend it to others, provided such loans carried with them security and a return. As marking the Industrial Revolution, capital was turned into the creation of goods on a larger scale and workers in an industry were brought together with the inauguration of the factory. Ownership and management came into existence on one hand, and specialized workers, in groups of gradually increasing numbers, on the other. It was not until the following century that, with the inauguration of steam as an immediate energy source, the Mechanical Revolution, as it was called, occurred. With such changes management and workers became more markedly segregated, and all existing problems of the modern production system arose.

In following these various steps in development, we find the principal incentive to be profit to the individual, which is carried on through the wage earner, money lender, owner, and operator of organized production. Our American economic system, with its various modifications and limitations, depends upon profit to the individual from effort expended and a right to hold such profits in the form of personal property. Industrial organizations were created and grew from the profit motive.

DEFINITION AND FUNCTION OF ORGANIZATION

Organization has been defined as the form of human associations for the attainment of some common purpose. The word "form" is vital here, since it gives us a clue to the difference between *organization* and *management*. Management is the force that coordinates the elements of the form or mechanism, and vitalizes the organization. The two words are closely correlated and are sometimes used synonymously.

Organization must weld together many different factors essential to the inception and maintenance of any industrial enterprise:

1. The entrepreneur, the individual or group of individuals who supplies the motivating force.
2. The product or service that is the excuse for bringing the enterprise into existence.
3. The "backing" in the form of liquid assets, land, buildings, equipment, and materials.
4. A plan for building and marketing the goods or services.
5. The working force for building and marketing the product or service.

When we consider all these factors that are found to make up even the most humble of industrial enterprises, we begin to visualize certain functions that must be fulfilled by the organization. Some authorities list an "irreducible minimum" of these functions that are absolutely essential to all manufacturing enterprises regardless of type or magnitude.

In some organizations, these functions may be performed by one man. In a large concern, the same functions may be distributed among 50,000 or 100,000 employees. These operating functions are:

1. Accounting and clerical.
2. Design, or product determination.
3. Purchasing.

4. Manufacturing—maintenance service.
5. Selling.
6. Industrial relations.
7. Public and customer relations.

The functions we have chosen to designate as "accounting and clerical" cover a complete system of records and reports in order that the executives may be kept in touch with conditions of the plant and of industry. An administrative standard must be set up, since the value of these reports lies chiefly in their ability to show how conditions of the enterprise or the industry as a whole compare with those of previous periods.

Some of the more important standards may be roughly grouped as financial, procedure, and operating. The financial standards embrace such concepts as the various ratios discussed in Chapter VII. The procedure standards coordinate the activities of the various departments and make it possible to detect the source of inefficiencies. Operating standards are, frequently, similar to financial standards, with this one exception: the financial standards permit comparisons only at stated intervals of a year or half year, whereas the operating standards permit running comparisons.

The records that are an integral part of the accounting and clerical function in organization are of varied types. They cover everything from the activities of sales engineers to the data on a drill press in the shop.

When we come to the engineering function, termed here as design or product determination, we find that its importance depends entirely on the product or service. If the product is simple of design and manufacture, the engineering function may be subordinated to the manufacturing department.[1] In a concern manufacturing products of a very technical nature, the engineering department is usually highly developed and established as a separate unit independent of the sales and manufacturing departments.

The main functions of the engineering department are resolved into two divisions:

1. The invention, design, and improvement of the products to be manufactured.

[1] For instance, in a line of apparatus such as textile machinery, the engineering design function is of outstanding importance and requires comprehensive facilities. In the manufacture of a technical product such as rayon, however, the parallel function, performed by those who determine the characteristics of the product to be made, may be performed by an individual or a very small group of individuals, and the big problem becomes that of manufacture.

2. The planning and determining of dies, tools, and other specialized equipment for use in the manufacturing operation, and establishing the limits for inspection and test of the finished product.

These engineering functions break down into such subdivisions as the study of product from the standpoint of efficiency and its adequacy for the ultimate usage and from the manufacturing standpoint.

The engineering department should cooperate with the sales department in investigating alleged failure or weakness of product. It should design special machinery required, study raw materials, determine the machines, tools, and gauges for use in the manufacturing operations, and furnish the engineering counsel necessary in making sales. In a few large concerns, the function of research is carried on by an independent department, but in the majority of establishments, this too comes under the engineering department.

We now come to the purchasing function. The purchasing department is of greater importance than is generally conceded, for, frequently, the margin of profit and the quality of product depend largely on the intelligent purchasing of raw materials, equipment, and supplies. The importance and the organization of the purchasing department will be considered at length in a later chapter.

Turning now to the manufacturing function, the manufacturing department is responsible for building the product itself. The manufacturing department must turn out a quality product at the lowest possible cost. It must make rush deliveries and meet special requirements for large customers; as it must attempt to please everyone, it has a difficult time pleasing anyone.

The sales *function in most concerns is made to include* actual selling, sales promotion, and advertising. Even in companies that devote separate departments to these functions, they are none the less closely coordinated. The sales department must select and train salesmen, establish a plan for selling each type of product, set up branch offices, establish district warehouses and distributors, and perform many other duties that will be taken up in later chapters.

The industrial relations function is one that has attained general recognition only of late years. Employers have been forced to realize the vital necessity of devoting attention to the problem of employer-employee relationships.

The extent of industrial relations work varies widely among industries and concerns in an industry. Personnel work includes the employment and training of workers, improvement of working conditions, welfare work, and orientation of the worker in his proper

sphere. Companies that give insufficient attention to personnel work, or carry on their industrial relations on an unsound basis, inevitably reap the whirlwind in the form of strikes or generally unsatisfactory employee conditions.

A function that has been even slower to gain general recognition is that of public relations. Bitter experience has shown that unfavorable news stories will nullify the effects of expensive sales and advertising campaigns. The good will of the buying public is one of the most valued assets that any business concern can have. And so it is that, if for none other than selfish reasons, many manufacturing and business companies have established departments the sole activity of which is to gain the good will of the general public. These public relations departments endeavor to present, to the public at large, the company's activities in the best possible light, and to have the message given nationwide circulation.

FINANCING AN ENTERPRISE

We shall find, in the topic that follows, the problem of the selection of the proper form of organization of an enterprise—that is, the choice between an individual proprietorship, a partnership, or a corporation. We shall further see that finance and the amount of capital required to get the enterprise started will have a great deal of bearing upon which form is the most desirable. Since every enterprise is faced with the problem of financing, we shall here merely outline why financing is necessary. The detailed methods of financing an enterprise, such as by private capital, loans, mortgages, and the sale of stocks and bonds,[2] are basic principles. For a detailed treatment of these methods, the student is referred to business handbooks and other books on business financing.

Why Is Financing Necessary? Suppose that we were starting a company to engage in the manufacture and distribution of a particular product. Besides a well-formulated plan for establishing and operating the enterprise, *funds* would also be required with which to purchase physical assets of all kinds necessary to carrying on our enterprise. Land, buildings, machinery, and equipment would be needed. Stocks of raw materials would be required, and salaries and wages would become due long before any products were available,

[2] The difference between stocks and bonds is often misunderstood. The share of stock represents *ownership* in the incorporated enterprise; the bond represents a funded *debt* of the enterprise to be paid at a stipulated time usually well in the future.

from the sale of which funds could be collected. Months and even years might pass before the income from sales equaled all the costs of production and distribution, since time would be required to organize and train factory and sales employees. Perhaps, in the meantime, unforeseen troubles might be experienced with production processes, or perhaps anticipated sales might not materialize owing to

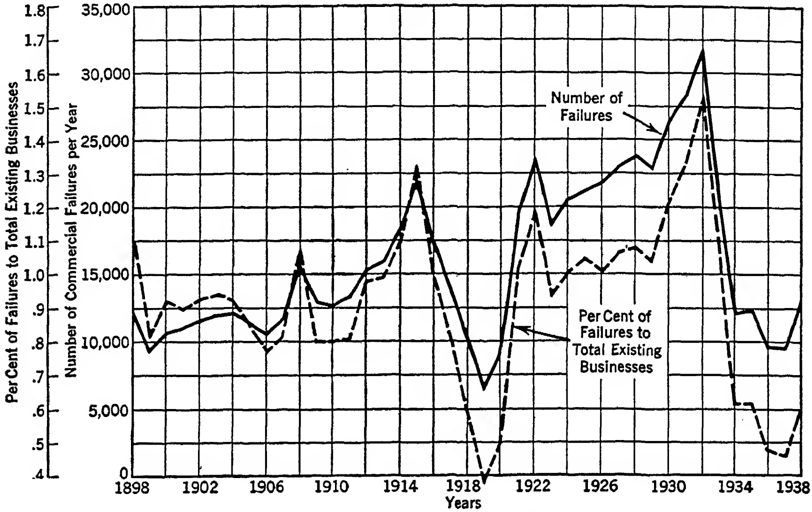

FIGURE 1. Industrial and commercial business failures in the United States. Data from *Dun's Review* (Dun and Bradstreet, Inc., New York City).

shrinkage in market demands. Hence, it often happens that available funds with which to carry on are lacking, and we realize that enterprises fail from having been *inadequately financed.*

Each year, thousands of business enterprises go out of existence[3] from lack of what we term "capital." Figure 1 clearly illustrates how this has been going on for many years.[4] Most companies fail

[3] Every day, on an average, 1142 corporations go out of business and 1292 new ones are created, according to Dun and Bradstreet. Obviously, many of these are small local business companies.

[4] It is of special interest to note, on this curve, the large number of failures occurring in 1932 and the years immediately preceding, followed by a great decrease in number of failures from 1934 through 1938. This sudden drop may be interpreted to mean that, as the depression struck, it forced most of the weaker businesses to fail, and since 1932 there has been little opportunity for other weaker ones to get under way and then fail. Also, stricter government regula-

because they are poorly managed, and the most common weakness on the part of management[5] is failure to provide for financing the enterprise. This holds true of any company, whether it is engaged in manufacturing, mining, distribution, construction, or the rendering of specialized service. Certain items, such as plant and equipment, may be rented instead of bought, but if one is to rent he must establish credit, and various risks and additional expenses are often incurred in so doing.

Funds are required, therefore, to:

Establish an enterprise on a basis originally planned.

Carry the enterprise on so that all bills are paid promptly and when due, in spite of varying conditions of purchase and sale.

Provide for activities of a development nature, such as the invention and perfection of new products to make and sell, or the embarking upon a sales promotional and advertising program.

Provide for major risks, such as extended periods of business depression, strikes of employees, or property loss, not all of which can be adequately predicted or provided for through insurance.

Furnish additional facilities of any kind necessary to growth and expansion of the enterprise.

Almost invariably, in newly formed concerns, and those managed by individuals lacking mature experience in financial as well as operating matters, we find that the expenses prove to be higher than those provided for in the original estimates.

Man power is the greatest asset any company has, because, from it, all progress emanates. Capital must be invested, therefore, in the selection and training of a group of individuals, and in providing an atmosphere in which they may work enthusiastically and harmoni-

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tions and extensive lending programs have served to reduce the number of failures to an almost all-time low.

Another interesting observation is the *general trend* of total business failures. If one establishes this trend on the curve, he will see that it shows total business failures to be on a rather steady increase. This trend does not mean, however, that a larger *proportion of the total number* of businesses are failing each year, for it must be remembered that the total number of businesses is also on the increase. In fact, the general trend of the total number of existing established businesses is very nearly parallel to the trend of the number of failures—both increasing at approximately the same rate. The curve of percentage of failures to total number of businesses bears out the fact that, taking the general trend over the years, the ratio of failures to total businesses is fairly constant.

[5] Recently, a prominent business executive, who has risen from the ranks of engineers, pointed out that the most valuable principle he had to learn, after leaving the technical school, was the importance of adequate resources and an ample cash balance in conducting a business successfully.

ously toward one end. The establishing of an organization of individuals requires financing. Useful patents which may be developed or purchased likewise require financing. Neither of these items, together with many more, can be seen and measured as can a piece of land, a factory, or a group of production machines—but nevertheless they have to be financed, and often the amount they will require is not readily predictable, and may easily be underestimated.

In much the same way, the contracting company which undertakes to build a structure must provide funds with which to proceed. Although the contracting company does not or will not own the structure, provision must be made for buying materials and paying workers—often long before any large volume of funds is received in payment for the undertaking.[6]

Similarly, we can easily visualize a new power plant being erected, with necessary equipment for generating, transforming, and distributing power. Such work must be complete and trained workers at their places of duty before one cent is received in revenue. Or again, a company operating a line of public service buses obtains a franchise from a city to operate on its streets. Several modern buses must be purchased and put into operation before a single fare is collected. Certainly such projects call for expert financing if they are to succeed.

And so we see that the first item we encounter in launching an enterprise is the demand for capital—the necessity of a plan for financing our business in its early stages and for keeping it in operation until the day we hope for arrives when the enterprise becomes self-supporting, and begins to make a return on its investment.

Credit. It is true that a concern can borrow money or buy materials or services with a "promise to pay" at some time in the future, but this cannot be done without *credit*, which will be mentioned briefly.

Credit is the power to obtain products or services through giving a promise to pay money, or anything else of specific value, upon demand or at a specified time. It must be noted that there must be a *willingness* and also an *ability* to pay, and a time specified when payment shall be made. Establishing credit, therefore, depends upon the reputation of the company or individual, which is based upon his

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[6] It is interesting to note in passing, for instance, that the Boulder Dam was built by the Six Companies, which was a newly formed organization consisting of a combination of six large contracting companies. No single existing contracting company was sufficiently large or financially responsible to undertake so large a contract and risk.

business habits and integrity, and also upon his financial condition. The last is easily determined at the time a loan is made, but the borrower's ability to pay when the obligation comes due is a "risk." Obviously, the further in the future the payment of the obligation is to be made, the greater is the risk involved, because as time passes conditions may undergo changes which will completely alter the financial condition of the borrower.[7]

We might further classify credit on the basis of its use. Credit extended for production purposes—that is, the borrowing of money for a plant site, buildings, and productive machinery, or what we term capital expenditures—is ordinarily considered *long-term credit.* If credit is granted for such purposes, many years may elapse before payment is to be made. On the other hand, credit extended upon a stock of steel in the hands of a small tool manufacturer, which might be accumulated when steel prices were low, is ordinarily considered *short-term credit* or *commercial credit*, because payment can be made with reasonable promptness as money becomes available from the sale of the finished products. Borrowing upon a stock of radio receiving sets in the hand of a distributor would likewise involve this sort of credit.

In the examples cited, both for long- and short-term credit, credit was established upon specific things of value. Sometimes, however, we find that credit is extended simply on the basis of integrity and financial responsibility of the concern to whom it is extended, irrespective of any particular object of value existing as security.

Surplus and Liquid Funds. The importance of the accumulation of a surplus in funds, and also holding a large share of such funds in liquid form, cannot be overemphasized. As the volume of business done by enterprises varies from year to year, resulting in a profit or a loss, it is essential to have set up a reserve making it possible to continue an enterprise during times of poor business. A much larger number of companies during the long depression of business extending from 1931 to 1936 would have failed if they had not accumulated a surplus, and also held a large share of this in liquid form. Some companies that experienced a loss during these years continued to pay dividends to their stockholders from the surplus that had been previously accumulated.

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[7] For this reason, "short-term loans" carry a lower interest rate, usually, than "long-term loans."

FORMS OF ORGANIZATION

The simplest and oldest form of business organization is the individual proprietorship, which is simply the individual in business for himself. No matter how complex the business organization may be, it is headed and owned by the proprietor.

Among the advantages generally attributed to the individual proprietorship are the ease of inception and termination of the enterprise. The policies are formulated by the proprietor, they can easily be modified to meet changed conditions, and the organization is flexible and less given to internal friction than one of any other form. In many ways the proprietorship can be likened to a dictatorship in government, since both partake of the same advantages of centralization, flexibility, and fixed responsibility.

But there is another side to the picture. The most serious limitation of the proprietorship in modern business is the amount of capital that any one man can assemble. In these days of enormous corporations, when one steel company spends $60,000,000 to construct a new plant, it is obvious how limited a concern would be if it were to depend on an individual owner for all its capital.

Another disadvantage of the individual proprietorship is the unlimited liability of the owner for all business debts. He stands to lose his entire personal fortune if his business should fail. Again, the possibility of the disruption of the business from the death of its owner is a disadvantage. And finally, the abilities needed to guide a modern business may be varied and much too extensive for any one man.

When the individual proprietor sees that he needs more capital or executive ability that only other men can furnish, what is more logical than for him to make one or more of his business associates partners in the concern? We thus simply and logically evolve the partnership,[8] a form of organization nearly as old as the individual proprietorship.

The partnership is characterized by numerous advantages and disadvantages, the most important of which are:

1. Ease of inception. An oral or written agreement between the contracting parties is all that is necessary in many states.
2. Mutual responsibility. Each partner is bound by the acts of the

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[8] A classic example of a partnership which developed into a very large organization and finally, owing to the size of its business, had to become incorporated, is that of Burnham and Williams of Philadelphia, which became the Baldwin Locomotive Company in 1909.

others in all business transactions. In some ways this may be a disadvantage; in others, it is advantageous in that it prevents the delegation of management characteristic of corporations.

3. Individual liability. Creditors sue each individual partner, since the partnership itself is not a legal entity. Since each partner is liable to the extent of his personal fortune, this feature presents the same disadvantage of unlimited liability that characterized the proprietorship.

4. The death or withdrawal of any partner automatically results in termination of the partnership, and a new partnership must be drawn up before business can be continued. This feature is also as disadvantageous as the similar characteristic of the proprietorship.

5. The partnership enjoys certain freedoms not granted to corporations. The partnership is more flexible in that it is not limited to any one type of business, whereas the corporation may pursue only the line for which it was incorporated. In addition, the partnership is free from many taxes and restraints imposed on corporations.

Thus, we see that the partnership has greater possibilities in raising of capital and in specialization of executive talent than the proprietorship. It maintains much of the flexibility, but is so unfortunate as also to share the proprietorship's unlimited liability and termination by death or withdrawal of the management.

The more modern form of organization is the corporation. In essence, it is founded on the pooled resources of many individuals, commonly termed the stockholders, since each has a share or "stock" in the ownership of the company. The corporation has rapidly become the dominant form of industrial organization[9] in the United States, owing to the advantage it possesses of almost unlimited capital, and to elimination of several other weaknesses found in the proprietorship and partnership.

Since a large corporation may be made up of thousands of stockholders, it is apparent that all these owners cannot be actively engaged in the management of the enterprise. In a business corporation, the owners delegate their responsibility to a board of directors or managers, often elected from their number. This board of directors elects a chairman, and to this group and its chairman the entire industrial organization of president, vice-presidents, managers, assistants, and so on, are responsible.

Certain characteristics distinguish a corporation from the other forms of organization that we have previously noted. They are:

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[9] The extent or growth of a corporation may be limited, in adhering closely to the production and distribution of a given product, by tending to become a monopoly in any one field, thus running counter to federal statutes.

1. Corporations obtain their capital from a subscription of stock, which is usually spread among a large number of individuals. In this manner a large corporation can gather together capital assets far surpassing those possible in the partnership or proprietorship.

2. These shares, denoting partial ownership in the concern, are readily transferable. This is a distinct and important difference from the partnership or proprietorship, where a change in ownership usually means a violent upheaval in the whole organization.

3. One of the most pronounced advantages of the corporate form of organization is that of limited liability. The shareholders are commonly liable for the debts of the corporation only up to the amount of their stock. This one factor alone has been accountable for much of the development of the corporate form of business organization in recent years.

4. Because of the large number of owners, the management of the corporate organization must of necessity be delegated. The delegation of active management has several aspects. It insures more efficient management. It attracts capital from the investor who wishes to share in the ownership, but lacks ability or opportunity to share in active management.

5. The corporate form of organization is characterized by perpetual succession throughout the span of its charter. Though owners or managers may die or change, legal entity still remains intact. This is another marked advantage over the partnership.

6. Corporations must confine their activities to those for which they were conceived. Unlike the older forms of organization, the corporation is by law forbidden to engage in activities not included in its charter. The importance of this is decreasing, since the charters are written in broad terms that impose few restrictions.

7. The corporation is legally a *person,* and consequently can sue or be sued. The vital significance of this is seen in the nature of court decisions, in which the courts generally have looked upon corporations as distinct, individual personages.

8. The corporation has a name and a seal as evidence of its distinct identity. It may be granted some unique powers and privileges. One of the best known of these is the right of eminent domain granted the public utilities, and permitting them to take over private property without consent of the owner, upon payment of reasonable compensation.

9. Corporations are formed by grant of authority from the state in which they are incorporated. Certain states, notorious for their liberality in these regards, are the legal "homes" of many corporations which conduct practically all their business in other states.

Perhaps the two most vital advantages the corporations enjoy over the partnership and proprietorship are those of limited liability and great potential capital resources. But the corporation has ob-

vious disadvantages. Among these are unwieldiness, inertia, and decentralization of responsibility. Internal friction, bureaucracy, and inflexibility are concomitants of the great size of corporate enterprises. They experience difficulty in adapting themselves suddenly to changed conditions, as has been already mentioned. Corporations *vs.* partnerships is similar in many ways to a form of democracy *vs.* dictatorship.

THE HOLDING COMPANY

The *holding company,* as a means of controlling more than one corporation, is the most widespread device in use today. It offers marked advantages over pools,[10], trusts,[11] trade associations, and similar forms of organization. The holding company secures control of a large corporation by purchase of a majority block of stock, or, in some cases, a small minority ownership gives actual control when it forms the balance of power between larger blocks.

The holding company has numerous uses and abuses, among which are the following:

1. In securing control of large industrial concerns by those who have little capital in the enterprise.

2. Evasion of the law. This is particularly true in the public utility field, in those states requiring that its utilities be operated by corporations chartered in that state. In this case, the stock of the utility is often owned by an outside holding company, thus controlling the utility without breaking the letter of the law.

   Evasion of government regulation is akin to this. Public utilities are subject to regulation by the government, whereas many holding companies have been outside of state control.

3. As contrasted to the looseness of pools and cartels,[12] the holding company gives complete control. It may have advantages over the fusion of two corporations, for the corporations do not lose their separate identities, minority stockholder's blocking of acquisition is forestalled, subsequent separation of the concerns is more readily accomplished, and the control of one by the other is brought about more economically. The economy of the control of several allied corporations by a holding company is often very marked in specialized functions of management and engi-

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[10] A *pool* is defined as any aggregation of the interests or property of different persons, made to further a joint undertaking.

[11] A *trust* is defined as a business organization or combination, consisting of a number of firms or corporations operating, and often united, under an agreement for the purpose of price, volume, or market control.

[12] A *cartel* is a form of combination originating in Germany and continuing in other European countries, for the purpose of control of price, territory, or market of a product.

neering, and in the joint activities such as purchasing, marketing, and advertising.

4. Holding companies make possible the pyramiding of earnings. A control of several corporations is secured by purchase of blocks of common stock, the capital to purchase this stock being obtained by sale of stock in the holding company. By means of this device of partial financing through fixed income securities, the moderate earnings of the controlled corporation give large earnings on the holding company stocks, but at greatly increased risk. An excellent illustrative example of this device can be found in "Organization and Management of a Business Enterprise" by Fenistrom, Elder, Fiske, Schaeffer and Thresher, Chapter VI.

TYPES OF ORGANIZATION

In the small, one-man type of business that we have already noted, the owner-manager directly heads every activity in the organization. If the concern is small, and the employees few, he can do this successfully. The owner may combine the functions of manager and shop foreman all in himself, and under him have workmen and an office force, all of whose activities he personally directs.

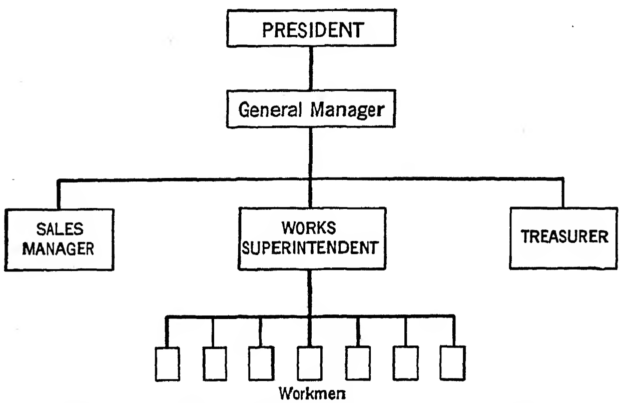

FIGURE 2. Line or military type of organization.

As this concern becomes larger in size, the activities become too numerous and broad to be directed by one man. The owner may give over active management to a general manager, who in turn may employ others to specialize in the production, the sales, and the financial functions. Thus, we find the organization becoming more complicated with the advent of specialization.

Figure 2 illustrates an organization such as that which we have just described, not very far removed from the one-man type of busi-

ness concern. This is usually referred to as the "military" or "line" type of organization, the former title due to its historical derivation, since it is patterned after the ancient type of military organization. Military control demanded that authority descend in a straight line from the general to the lowest-ranking warrior. The general gave orders to his subordinates, the latter to their subordinates—on down to the regular soldier. In our chart in Fig. 2, we see that the owner gives orders to the manager, the manager to the sales, financial, and works superintendents, and so on down to the workmen. The larger this type of organization grows to be, the larger is the number of

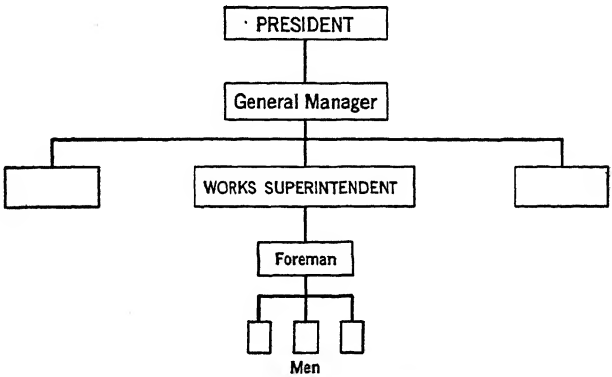

FIGURE 3. Line type of organization with a foreman over a few workmen.

assistants required, and the distance from owner to worker becomes greater and greater.

This type of organization possesses certain marked advantages as long as it does not grow too large. Responsibility is clearly defined, discipline is readily maintained, and action is direct.

For the best understanding of the disadvantages, let us turn to Fig. 3.[13] Here we have a leader—let us say a shop foreman—under the line type of organization, with three men directly under him.

In this concern the foreman spends about one-third of his time in overseeing the efforts of his employees, one-third in actual work with his hands, and the other one-third in attending to such routine matters as correspondence and personnel work.

All is well and good, as long as the number of workers is small.

[13] As we progressively illustrate the forms of organizations by means of diagrams (Figs. 3, 4, 5, 6 and 7), for the sake of simplicity we will expand the details of the diagram only in so far as it relates to manufacture.

But let us consider Fig. 4 to see what happens as the organization expands. Here we see that the foreman has to give up entirely any actual hand work. He spends about two-thirds of his time in overseeing his employees, and in the remaining one-third attempts to keep up with the increased amount of detailed work. His control over his subordinates is weaker, and the advantages of the line organization are being outweighed by the disadvantages.

The only answer to this is to divide up the workers into two groups, put a subforeman over each group, and have these subforemen report to the foreman. The subforemen are then free to spend most of their time in an advisory capacity, and the foreman devotes the majority of his time to plans and direction. This is shown in Fig. 5.

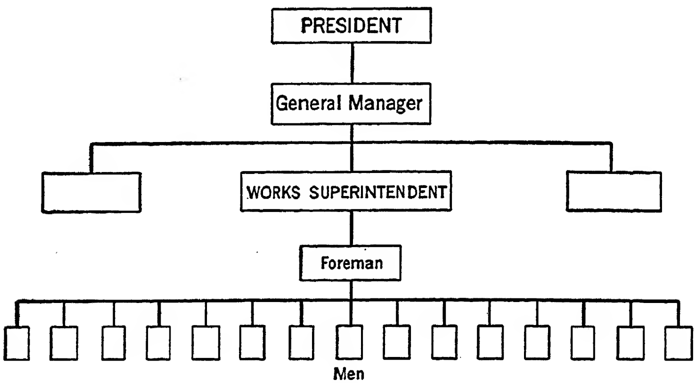

FIGURE 4. Line type of organization with a foreman over many workmen. Much of the foreman's time must be spent in overseeing.

The main weaknesses of the military type of organization are that it asks more of the foreman than is humanly possible for him to perform. He must oversee the activities of his men, a job in itself. In addition to this, he must handle all the routine, employ and release men, instruct them, do all the planning and layout work, and so on. He is responsible for the shop work, and is in entire charge of all that goes on there. It is obvious that this type of organization has very definite limits as to size.

Summing up the disadvantages of the military organization, we find:

1. That it demands more of the men than is humanly possible for them to perform, and men sufficiently capable are almost impossible to find.

2. That leaders are overloaded with details so that they cannot devote sufficient time to executive work.

3. It fails to utilize specialization, with the result that work is not done efficiently, and costs are likely to be excessive.

4. Discipline, rather than cooperation, is the impelling force.

If a concern is expanding to the point where the old line organization is no longer satisfactory, what, then, is the solution? How should we reorganize to form a smooth-running business?

The line and staff organization[14] is a partial answer, but it likewise is subject to size limitations. This form is merely the military organization with the addition of a staff to take the burden of details

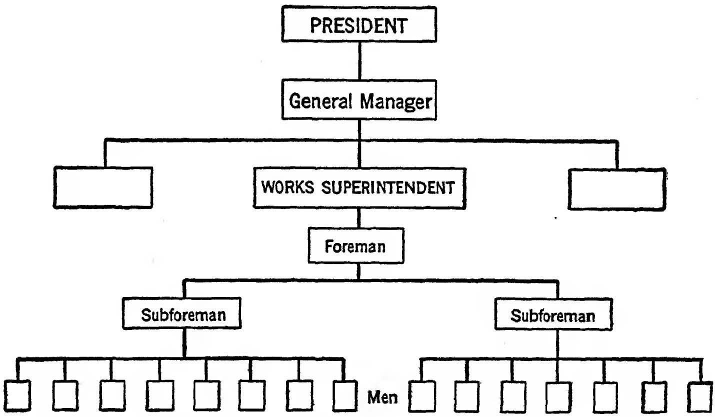

FIGURE 5. Line type of organization with subforemen taking over much of the overseeing previously done by foreman, leaving his time free for other, more important duties.

from the executive's shoulders. The leaders, be they managers or group leaders, are then able to utilize more of their time for making decisions on policy, and such work.

Figure 6 shows how the staff may conceivably be added to a straight-line organization. The addition of a production expert as an assistant to the works manager relieves the manager of much of this phase of his duties, and the clerks assume many of the onerous details that take up valuable time which the foreman should devote to other work.

As our mythical organization continues to expand, we soon find that the addition of a staff is but a temporary expedient, and a radi-

[14] Reference: "Executive Responsibility," Edgar W. Smith, *The Society for the Advancement of Management Journal*, January, 1938, p. 29.

cally different form of organization is necessary. This need is filled by the "functional" type. The functional organization makes a high degree of specialization possible, and utilizes division of labor to a great extent. The necessity for "all-round" men, so essential to the line organization, is completely done away with.

The functional organization, as its name indicates, divides the work up into functions, and abolishes the direct line of authority found in the military form. A specialist heads each function or group of associated functions. These executive specialists have charge

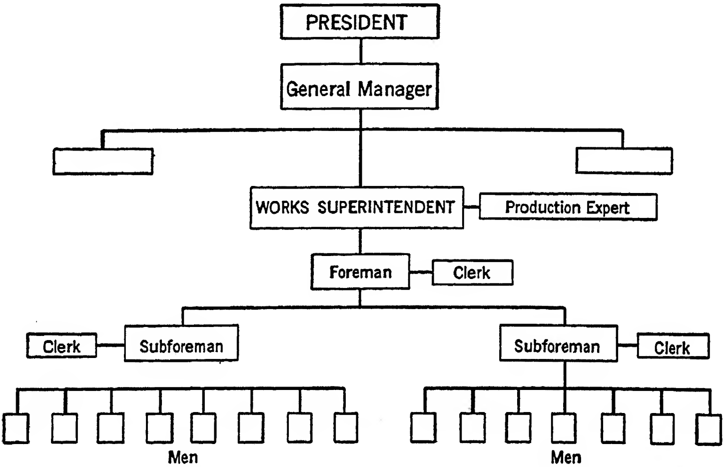

FIGURE 6. Line with staff organization. Staff includes production expert as assistant to works superintendent, and clerks assisting the foreman and subformen.

of their particular activity throughout the organization, no matter where these functions are found.

For example, the director of personnel hires all employees for the various departments. The chief engineer heads up engineering throughout the organization; even though the company has ten plants manufacturing as many products, the chief engineer is responsible for the engineering work on all these products in each plant. The executive in charge of purchasing buys the materials and supplies for all plants and all departments of the organization.

Figure 7 shows one theoretical functional organization in which engineering, works, and personnel departments pursue their functions through all departments of the organization, including stock layout and routing, time study, cost, service, materials, inspection, and others.

In the functional type of organization, the worker takes his orders from more than one foreman or group leader. The various functions which affect the worker are headed up by the different supervisors, and each in turn has control over the worker in the performance of that function. Each supervisor, by performing only one duty, should, theoretically, become an expert in that line, and the worker *should* benefit from getting expert attention in all the different lines, such as planning, rates, personnel, dies and fixtures, and inspection. The

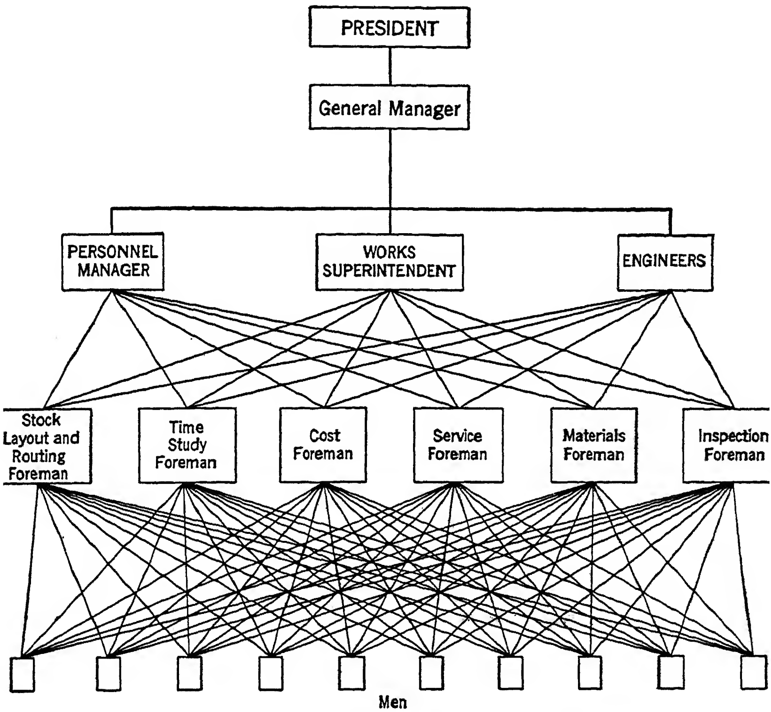

FIGURE 7. Theoretical functional organization chart.

disadvantage of the functional type of organization lies in the fact that, for a particular product, for instance, there is no single individual in charge of activities in connection with it, and therefore, with this type of organization there is a lack of fixed responsibility.

Figure 8 shows a functional type of organization actually in use in a large company manufacturing a number of different products, only four of which are shown on this chart.

In an actual business concern, the organization is likely to be a

combination of the line, the line and staff, and the functional types. Each of these forms has its advantages and disadvantages. The larger the concern, the more difficult it is to coordinate all departments and activities. One composite method now often used by the large concern is known as the divisional type, and is illustrated in Fig. 9. Here each division is headed up by a manager reporting to the general manager. Each division is a unit unto itself, the head-

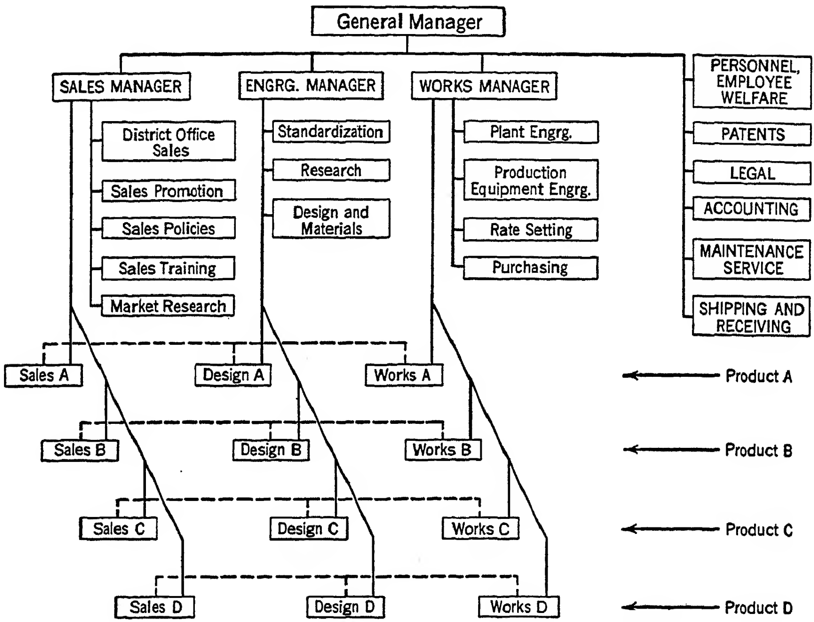

FIGURE 8. One form of the functional type of organization in actual use by a large company manufacturing a number of products.

quarters sales, engineering, and works managers acting in an advisory capacity.

There are indisputable advantages in having such activities as purchasing on a functional basis. And, at the same time, there are distinct advantages in dividing certain activities up into separate operating divisions; each, in a sense, pitted against the other and responsible for a profit. Modern management recognizes this, and, as a result of this recognition, the larger business organizations of today are "cross-breeds," combining the functional, military, and line and staff as advantageously as possible.

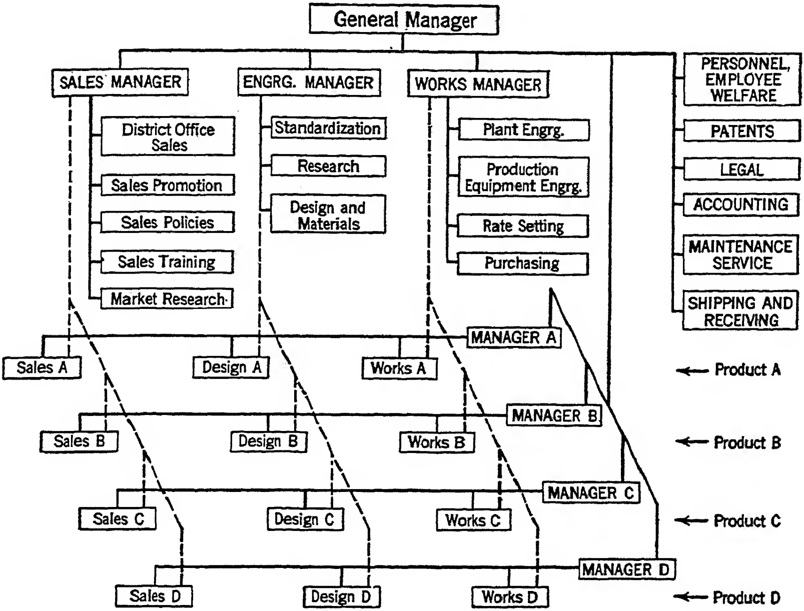

FIGURE 9. The divisional type of organization.

FACTORS IN SELECTING THE TYPE OF ORGANIZATION

From a study of the growth of individual organizations and the modifications that have taken place in the form of these, it will be readily seen that several factors may have an influence in determining these changes. They may be summarized as follows:

Purpose of the Organization. The organizations cited are those engaged in the production and distribution of products of a technical character. Such organizations are more complicated than those formed for rendering a service or performing a particular function, as, for instance, a firm of engineers or architects, a distributor, a maintenance service company, or a construction contractor.

Size of the Organization. It is obvious that, as an enterprise grows in size, the amount of specialized effort increases, justifying individuals being assigned solely to certain lines of work, where, in small enterprise, one individual may perform more than one function.

Variety of Products or Services. The enterprise which makes only one product requires a simpler organization than one which makes a variety of products.

We cannot do more than mention, in passing, a few other factors, in the hope that they will be thought-provoking. The degree of control over expense that is needed enters into the determination of the type of organization. The need for interrelating of functional activities varies greatly, and is a determinant.

The ease of functioning and set-up necessary for doing its daily business, is not the same in every line of activity, and this should be considered. If the concern is large with a far-flung network of plants, warehouses, and offices, the factor of geographic location will obviously enter the picture. And, from the sales point of view particularly, the location and type of the market are of importance in setting up the organization.

The development of a form of organization, then, is almost always a matter of compromise, for no one can say that exactly this or that particular type of organization is the only one suited for the purpose. Often, in business today, we find two enterprises engaged in very much the same line of work, subject to the same general conditions, wherein there exist some rather marked differences when it comes to the details of organization, yet both enterprises are carried on successfully. Much depends upon the personal characteristics and attitude of the management and those developed in each employee, for, unless all employees work together enthusiastically and cooperatively, results cannot be obtained even by the enterprise which we consider to be perfectly organized.

Reference

Marvin Bower, "Untangling the Corporate Harness," *Mechanical Engineering*, December, 1938, p. 904.

MISCELLANEOUS CONCEPTS

System. A word that is often misunderstood is "system." As applied to industrial organizations, system may be defined as embracing the methods of procedure that have been planned for reducing the bulk of the daily work to a routine. That the flow of daily work must be directed into routine channels for the sake of efficiency is self-evident. System makes it possible for work otherwise attended to by executives to be safely performed by less skilled persons, and thus leaves the time of the executive free for planning and directing. "System" is really a plan of procedure, from the mere detail of filing papers on throughout all the work that is done in the organization.

Red Tape. System is often referred to in a derogatory manner as "red tape." Red tape is actually the misapplication of system.

When the daily functioning of business is impeded, rather than facilitated, by the system, then the observer contemptuously condemns the seemingly petty details as "too much red tape." There is a tendency in large organizations to oversystematize, usually with more or less disastrous results. But it must be realized that even the best applied system is seemingly inflexible to anything that opposes it, or attempts to hasten it. For instance, a concern may have set up an excellent system for receiving, approving, and entering orders. This system works smoothly, perhaps without anyone being aware of its existence, until someone tries to put through an order in a different manner, or attempts to rush it through. The result will be a snarl and confusion that is unbelievable.[15] This is not "red tape"; it is the misuse of "system"—a system that is perfectly satisfactory for the ordinary run of business, but inflexible to any deviation.

Committees. The committee is a common tool in industrial organizations to reach a certain kind of result. It best functions in an investigating and advisory capacity, rather than an executive capacity. Executive action, by and through committees, is usually slow and tedious, and there is an inclination for any one committee member to side-step direct responsibility. The group composing the committee, to be effective, should be made up of individuals vitally concerned in the various branches of work under consideration.

An obvious purpose of the committee is to uncover ideas and suggestions that will lead to the better management of the concern. A less apparent, more subtle, objective is to further cooperation between different departments and divisions of the organization. The members of the committee feel that they are shaping the company's policies. They are given a more profound understanding of the other fellow's problems. They feel a responsibility, and a sense of loyalty, conducive to the best interests of all concerned.

THE PERSONALITY OF AN ORGANIZATION

An industrial organization acquires a personality just as does an individual, because it consists of a group of individuals with a varying degree of principle and purpose. The closer the group works

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[15] An owner of a certain make of radio living a distance from any authorized dealer broke the drive belt on his radio dial. Wishing to install it himself and hoping to hurry the belt's delivery, he sent direct to the factory for it, instead of ordering through a dealer. As a result of this order, which was entered contrary to established system, the owner negotiated two months before he received his belt—a 15c item.

together and the more clearly defined the policies and objectives are, the easier it becomes to apprehend and visualize the personality of the organization. Management is coming to realize this more and more, and to appreciate the value of reputation and personality. The expression "soulless corporation" has been current a long time, and many corporations have existed in the minds of the public as possessing neither principle, personality, nor conscience. This is because some managements have had the impression that successful operation consists of making a good profit at the expense of everything else.[16] Our ideas are also changing about what constitutes a successful organization, and management's ideas are changing to the belief that, to be permanently successful financially, a higher set of principles is necessary, and a broader view as to the nature of responsibilities is needed.

Industrial organizations differ greatly in the extent of relationship with the public. The railroad personally comes in contact with a large variety of people over wide areas, through the nature of its service, whereas the manufacturer of air brakes may come into direct contact with but a very few, aside from the communities wherein its manufacturing plants are located.

ESTABLISHING A REPUTATION

The reputation of an individual organization is established in a number of ways, and the public forms opinions both favorable and unfavorable which constitute one of the most valuable or deterring influences toward success or failure that a company can have. News travels in a thousand ways, and as we have seen business is done to an extent by the reaction of the emotions. Impressions are created and opinions formed regarding an organization through contacts of every sort.

A mail-order house selling entirely by means of a catalogue might appear to represent a company having the minimum number of avenues of contact. Besides the catalogue itself, the company's reputation is created by the quality of products it sells, the form and manner in which inquiries and orders are handled, and the attitude

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[16] "In the complex industrial society under which we now live, management no longer represents, as formerly, a single interest; increasingly it functions on the basis of a trustee-ship, endeavoring to maintain a proper balance of equity between four basic interlocking groups: the shareholders . . . the jobholders . . . the customers . . . the public." From "Management's Aims and Responsibilities," Lewis H. Brown, *Factory Management and Maintenance,* October, 1938, p. 56.

in the collection of accounts and correction of errors. In the district where employees are located, the attitude and action of each employee influence the reputation of the company. Every notice in the magazines and daily papers creates some impression—either good or bad—and the name of the company cannot be mentioned once without some influence being created which either helps or hinders the company's progress and success. Its contacts with its suppliers create a large sphere of influence, as well as the contacts with those who transport goods both purchased and sold by this firm.

For a manufacturer building and selling industrial products, these same forces for creating favorable or unfavorable opinion exist, and are still further multiplied because usually both salesmen and distributors are required in reaching the market, and their every word and act carries an influence.

When we consider those companies which supply products or services required by a large number of people such as electricity, transportation, and communication services, the contact becomes most intimate. In such instances, the establishing of good will constitutes the most important factor in creating a favorable reputation.

Some years ago the representative of a large potential purchaser appeared unannounced at the office of an eastern manufacturer. Certain impressions of the manufacturer had been created in this individual's mind which were definitely favorable to this particular supplier. Upon his arrival at the manufacturer's reception room, he was treated in an officious manner by the attendant, and made to wait for an interview without being given any reason for the delay. He finally left without the interview, and eventually placed a valuable contract for equipment, desired by this particular manufacturer, elsewhere. After the difficulty was finally discovered, years passed and much expense was experienced before the manufacturer was able to re-establish his good will. In the meantime, additional valuable business was lost.

The reputation of an industrial company is relatively as valuable to it as the reputation of an individual to his own success and happiness. Consequently, the wise and well-managed company provides within its organization capable individuals who watch and guide matters of public relations. Truthful information possessing news value is furnished to the various avenues which reach the public, and events which might appear harmful if improperly understood and interpreted are explained in sufficient detail to be completely understood. To be effective, such publicity must be truthful and also properly directed

as to the audience it reaches. Every major policy or project adopted by an industrial company requires study, therefore, not only from the economic viewpoint, but also in regard to the effect that will be created in the minds of all whom the company, in the slightest degree, attempts to serve.

Reference

James W. Irwin, "A Practical Viewpoint on Public Relations," *Industrial Marketing,* January, 1939, p. 17.

CHAPTER V

STANDARDS AND STANDARDIZATION

Nothing could be more false than the popular concept of standardization as a strictly modern tendency. True it is that systems of standardization developed to so high a degree are due in no small amount to our modern mass-production methods. So far has this been carried that a hue and cry is sometimes raised lest the worker himself become standardized and reduced to a robot machine tender. But, actually, standards are as old as mankind.

The origin of standards reaches back into the very dawn of history. Our forbears, experimenting with their stone axes and spears, unwittingly set up crude standards for the construction and performance of weapons. With the formation of groups of people, rules for conduct and definite forms, sizes, and weights of articles for barter were soon found necessary to daily life. The family itself was a standard; speech, clothing, pictures, writing, religion, and division of time were all as truly a form of standardization as is the assembly line of a modern automobile factory.

INDUSTRIAL STANDARDIZATION

The thing that interests us even more than standards in general, and their evolution, is industrial standardization. Industrial standardization involves [1] (1) making the techniques of the various manufacturing processes as uniformly similar and as simple as possible; and (2) setting up a criterion for judging materials used in these processes, and the quality of the resulting product. The first aspect has a tendency to prevent manufacturing inefficiency and to promote engineering development. The second encourages economy in the purchasing function and maintains the product's quality and uniformity.

Standardization should not be looked upon as a static thing. Admittedly, standardization usually brings with it a large measure of

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[1] Reference: "How Standards are Set," *American Machinist*, June 29, 1938, p. 551. An insight into the way one company—the Chevrolet Motor Car Company—sets its standards and the organization for doing so.

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inertia.[2] Once materials and processes are standardized, drastic or sudden changes are immeasurably more difficult. This is brought about by the time and effort that are involved in making a change in the specifications or standards of a material or process. Likewise, it costs money to change the standards, and this serves to prevent random, drastic, or sudden changes in existing materials. Many other factors enter in, and all make for a stability of existing standards. However, modern standardization is dynamic. The standards, once set, are not maintained intact *if changes are desirable.* They may be changed, if it is found advisable, upon a thorough investigation, to suit better the product, the market, or the new processes. Industrial standards do not preclude change; they are set up in the best known way at the time, and are open to subsequent improvements as required. Standards are rarely inflexible, but permit variations that are *sufficiently liberal* for economic production, and yet *stiff enough* to maintain quality of the product.

The highest form of industrial standardization is found in America. Mass production of component parts to within five ten-thousandths of an inch tolerance is taken as a matter of course in many of the United States aircraft factories. Such accuracies permit absolute interchangeability[3] of parts, which is something that European manufacturers have not, as yet, extensively attained. The importance of this factor—interchangeability—can scarcely be overestimated. Complete interchangeability of parts has made the modern system of mass production possible. Only when component parts have been so completely standardized that they go together without any fitting is real mass production feasible.[4]

References

Frank B. Jewett, "Some Fundamentals in Standardization," *Electrical Engineering,* February, 1938, p. 57.

C. M. Cogan and A. B. Smith, "Standardization Pays," *Electrical Manufacturing,* May, 1938, p. 50.

[2] Consider how difficult it would be if we were to change our standards of time, currency, weights and measures, and how great would be the initial expense aside from the ultimate saving.

[3] It is interesting to note how interchangeability of parts has spread even to locomotive design. When a large Western railroad took delivery, in 1938, on its new high-capacity locomotives for fast freight and passenger service, a dominant feature was the many parts which were interchangeable with those of previous

[4] The classic example of this is this incident regarding LeLand's Cadillac cars. In the early days of automobiles, "Three cars were chosen at random from the

STANDARDS OF MATERIALS

The standardization of materials purchased by manufacturing companies simplifies the relations between supplier and buyer; it insures the buyer's getting exactly what he wants; and it usually results in substantial savings to the buyer, owing to the reduction of grades and types of materials to be purchased. A successful plan for standardization must, of necessity, be a compromise between factors that vary between plants of the same company and even between divisions of one plant. For instance, it may be that two separate plants have conditions of operation so different that raw materials meeting the rigid standards of one plant still are not sufficiently good for use in the other. The standards must, therefore, be set higher than required at one plant in order to satisfy the other, if both are to receive materials under the same set of standards. Likewise, it may be that one plant can turn out a product to much closer tolerances and of better quality than another. Here, it is readily seen that, if one standard is to be used for all products of this kind from all plants, the chosen standard must be the results of a thorough study of the conditions at each point of this standard's application. Otherwise, there will be much waste and rejection that may really not be justified.

The usual tendency for those who engineer a structure is away from standards. This is readily understood, since it is easier for an engineer to develop a design when he has an unlimited choice of sizes and grades of materials to incorporate in the design. Yet, in the interests of economy and efficiency, a decidedly restraining influence must be exerted on all inclinations toward unnecessarily varied

warehouse of the Cadillac agency in London, the cars were taken to Brookland's track and completely dismantled and the parts were placed in one conglomerate heap. Duplicates from the stock of spares were substituted for 69 parts in the pile; then three complete sets of parts were taken from the main heap without regard to the cars from which they were originally taken, and three 'new' cars were assembled. The only tools allowed were wrenches and screw drivers; no files or emery cloth. After being assembled, all of the cars were started with a few turns of the crank and were driven several hundred miles on the track." *S.A.E. Journal,* May, 1932, p. 37.

This "feat" does not seem so tremendous to us today, but in those days it was accounted such an achievement that the Cadillac car was awarded the Dewar trophy for this very performance. Interchangeability is, in this age, largely taken for granted. Actually, it is a development that would have been deemed utterly impossible a few decades ago, and is one of the most remarkable features of standardization.

lots of materials.[5] Material standards are largely controlled by the design requirements of the finished product, and economy in purchasing and stocking.[6] Many requirements must be met wholly, or in part, chief of which are:

1. Furnishing sufficient sizes and grades to meet reasonable design requirement.
2. Avoiding a superfluity of sizes and grades, or a deficiency of the same, in both cases in the interest of economy.
3. Standards should be in compliance with trade practices in order that the materials may be procured at a minimum cost and with maximum availability.
4. A logical system for selection of sizes and grades in rational and economical steps.
5. Coordination between the various plants or departments in large concerns, so that purchases may be lumped and stocks interchanged.

Obviously, a system of standards designed to meet these points must be a compromise.

Still further complications ensue from another essential requirement of a good standards system—that of flexibility. A good system of standardization of materials will permit:

1. Addition of new grades and sizes, should they be needed, according to some established plan.
2. Dropping of superseded sizes and grades economically, with a minimum of loss of material and change of records.
3. Simplification of grades and sizes already stocked. (Reduction of the amount of standards employed.)

Economy studies must be made to determine whether or not it is economical to stock an additional size or grade of material. A compromise between waste incurred due to large steps between sizes, and

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[5] Reference: "Design is Simplified by Use of Standard Parts," Walter Nichols, *Machine Design,* September, 1938, p. 21.

[6] A producer of grinding wheels has pointed out that his company has standardized upon some 20,000 different grinding wheels, each standard covering a wheel differing as to shape or material. A large share of these is carried in stock. When little sales movement is shown over a period of years for a particular style, stock of that style is no longer carried, and individual customer requirements are met by building wheels for the particular order, at a material increase in cost. This illustrates the importance both of standardization and the economics of producing a standard product for stock requirements, *versus* specially built equipment to meet the requirements of an individual order.

Reference

"87 American Standards of Special Interest in Operating Manufacturing Industries," *Industrial Standards,* March, 1937, p. 78.

costs of stocking many sizes, has to be reached. The following example should show the variety of factors which enter into a solution of a problem of this sort:

A storeroom in a certain plant carries in stock steel of 0.120-in. thickness. One class of apparatus being built in this plant requires steel of only 0.100-in. thickness. Would it be more economical to stock the thinner steel sheets, or should the thicker steel that is now stocked be used?

In order to solve this problem, the plant manager must know the amount of activity expected, the storeroom costs in regard to stocking new material, the steel costs, and the extra costs, if any, incurred by using the steel of additional thickness.

In this problem, the following will be assumed as representative data from which to work:

Data on Stocked Material

Thickness	0.120 in.
Cost per 100 lb.	$2.00
Storeroom costs	None
"Extra" costs [7] for working the thicker steel	$0.20/cwt
Waste due to extra unnecessary thickness	20%

Data on Non-Stocked Material

Thickness	0.100 in.
Cost per 100 lb.	$2.00
Storeroom costs due to making the new material a stock item and stocking it for use	$200.00/year
"Extra" costs	None
Waste	None

Case 1. Assume an activity requiring the use of 10,000 lb. of steel per year:

Using stocked material, 0.120-in. thickness, the annual costs are:

Steel costs[8] = (10,000 + 2,000)/100 × $2.00 =	$240
"Extra" costs = (10,000 + 2,000)/100 × $0.20 =	24
Total costs per year using 0.120-in. stocked material	$264

[7] Extra expenses in cutting, drilling, and other operations involved due to the increased, unnecessary thickness, over and above operational expenses on the 0.100 in. steel.

[8] Although the yearly demand for steel is 10,000 and 100,000 lb. respectively in Cases 1 and 2, in using the unnecessarily thick steel, an additional 20 per cent must be added for the weight of the unnecessary extra 0.020 in. in thickness, or 2000 lb. in Case 1 and 20,000 in Case 2. Likewise, "extra" costs must be figured on total weight of steel rather than demand weight, where the thicker steel is being used.

Using non-stocked material, 0.100-in. thickness, the annual costs are:

Steel costs = 10,000/100 × \$2.00 =	\$200
Storeroom costs per year to stock new material	200
Total costs per year using 0.100-in. material	\$400

It appears, then, that it is more economical by some \$136 per year (\$400 − \$264) to use the 0.120-in. material that is already stocked, and not put the 0.100-in. steel in stock, despite the waste, provided that the activity is but 10,000 lb. per year.

Case 2. Assume, next, an activity ten times that of the first case or one requiring 100,000 lb. of steel per year:

Using stocked material, 0.120-in. thickness, the annual costs are:

Steel costs[8] = (100,000 + 20,000)/100 × \$2.00 =	\$2400
"Extra" costs = (100,000 + 20,000)/100 × \$0.20 =	240
Total costs per year using 0.120-in. stocked material	\$2640

Using non-stocked material, 0.100-in. thickness, the annual costs are:

Steel costs = 100,000/100 × \$2.00 =	\$2000
Storeroom costs per year to stock new material	200
Total costs per year using 0.100-in. material	\$2200

On activity of ten times that of Case 1, or 100,000 lb. per year, it appears much more economical to stock and use the new 0.100-in. material, since, with this activity, a saving of \$440 per year is effected.

Summarizing such a solution, it may be seen that apparently the storeroom charges for using the non-stocked gauge in Case 1 would be too great, in comparison with the amount lost by the excess thickness and extra charge, to make it a paying proposition to use the 0.100-in. steel. Therefore, the new gauge would not be stocked.

In Case 2, however, the great activity results in so large a waste, due to excess thickness and extra charges, that the storeroom charges are overweighed, and it would therefore be advisable to stock the new gauge.

This, of course, is one of the simplest cases that could occur in industry. Many other factors might be considered in an actual problem of this sort which would complicate matters and make a decision more difficult to reach. Also, great care is necessary in determining accu-

rately those factors which have been considered. For instance, an error made in estimating the "extra" charges incurred by using the thicker steel—that is, extra costs in the form of labor in cutting, drilling, and so on—could make our decision an inaccurate and worthless one.

SPECIFICATIONS

The use of specifications in purchasing is a modern development. The enormous expansion of industry in the past few decades has brought with it a corresponding increase in the variety of materials that must be purchased. It is no longer possible for a manufacturer to order merely "steel." The grade and analysis must be specified to get steel best suited to the need. Similarly, a manufacturer who wishes some gears to incorporate into his product must specify the heat treatment, Brinell hardness, and similar standardized characteristics, as well as the familiar diametral pitch, number of teeth, and so on.

To meet this changed condition, manufacturers now "buy on specifications." Strictly speaking, a specification is a definition of work that is intended to be purchased in relation to either materials or services. This means that the purchasing department of an existing concern must cooperate with the engineering and manufacturing departments in preparing a list of all the qualities that must be possessed by the material or product purchased, as well as a list of tests that it must withstand. Such lists become "specifications," and are recorded and used whenever a new supply of the material is bought. The entire subject of purchasing is so broad and important that a chapter will be devoted to it later on in this book.

In true industrial standardization, specifications themselves are further standardized and simplified. That is, instead of having as many specifications as there are types or varieties of materials, one standard specification may be made adaptable to various items, and hence the number of specifications written is reduced and simplified greatly. Sometimes, a purchase may involve a group of materials whereby a newly written specification may be eliminated by grouping and combining several existing standard specifications. Hence, by so eliminating and consolidating non-essential specifications, their number can be cut down and subsequent savings made. Uniformity in form and structure of specifications, likewise, is important toward economy in the use of standards.

Specifications may be put to a variety of uses, but all of them have to do with some form of standard practice. In the purchase of materials, specifications serve to set up the requirements of the material

so that it will be certain to meet those standards which apply to it. Specifications are used often as a substitute for a sample where a product of certain exact characteristics is required, and yet no duplicate is available to serve as a pattern or sample.

Since specifications go hand in hand with standardization, the former being usually a definition of the latter, it is not difficult to see that, in many industrial transactions, the specification, if carefully written and clearly stated, is of just as much benefit to the seller or supplier as it is to the purchaser. True enough, the supplier of a product is held rigidly to that which he agrees to furnish the purchaser, but at the same time the rule works both ways and the supplier has, in the specification, a clear definition of the *minimum* which he must deliver, and hence he is relieved of any responsibility of going beyond this minimum unless he chooses to do so. This shows how very important it is that both the writer and the recipient of a set of specifications know exactly what is entailed before a transaction is consummated.

It is well to mention, in concluding, those important points that go to make up a sound specification which is neither weak in its purpose nor too rigid in its requirements. These points are summarized as follows:

> 1. The specification must give, in full detail, the results that are to be obtained within the defined limits. This requires definition of type and qualities of materials to be employed, as well as definition of the final form and service expected of the product.
>
> 2. The specification should be written in a clear and concise manner, so that detailed requirements can be clearly understood.
>
> 3. So long as the results adhere to the requirements for the finished product, as set up by the purchaser, the specification should restrict the supplier just as little as possible as regards his methods of procedure.

Many standardized products are furnished in accordance with a specification issued and published by the supplier. The nature of the specification is, of course, based upon previous experience as to what numerous customers need. However, with the supplier applying to a given product a simple symbol of identification such as a style or type number, the purchaser can order in this way, knowing that in so doing he will obtain a product which the supplier furnishes according to a given guaranteed standard.

See *American Machinist*, June 16, 1937, p. 539, for a well-organized material purchasing specification as prepared by International Business Machines Corporation.

SIMPLIFICATION

The last topic prepared us, somewhat, for the idea of simplification in standardization. Simplification may be defined as the next step after standardization. It is the reduction of the number of standards. In many instances great savings [9] have been made through the simplification of types, sizes, and grades in the matter of standardization. Whether it be the number of varieties of a product that a plant produces, or the varieties of some material it purchases, the reduction in number of types, sizes, and grades is all-important to economic procedure.

Despite the evident advantages of simplification, it is uneconomical, and often unsound, if it is carried to the extreme. Should a new process or product or an improvement over an old one be found, the first thought would be to scrap the old. But a manufacturer who has thousands of dollars' worth of the old product in his storerooms would think twice before doing anything so drastic. Many times a double standard is set up temporarily whereby the old material or product is gradually worked out, while the new is put into production and into stock. Even then, the problem is not ended—for how long should renewal

[9] A large electrical goods manufacturer found that, by standardizing the 1350 varieties of washers used in his plants, 150 sizes would be sufficient. By this reduction, as much as $25,000 was saved each year.

The same manufacturer saved approximately $50,000 per year by standardizing the fabrics used for treated insulation. In the course of years, the greatest activity had centered on goods that were not market standards. By changing over, wherever possible, to market standards, this saving was realized.

A manufacturer of motors and generators reduced the number of oil rings carried in stock from 220 to 50 sizes. In another organization, oil gauges were reduced in number from 72 to 45, contact screws from 203 to 98, and the variety of pins from 2631 to 1086—all such reductions resulting in worthwhile savings to the manufacturer.

One manufacturer of special machinery was using more than 1100 different pins for securing cams on shafts. Another manufacturing company used 1000 different varieties of miter gears for driving two shafts at right angles at a one-to-one speed ratio. The same company stocked five cylindrical pins of the same size, two of them nearly obsolete, two made up in job lots, and the fifth made up on an automatic screw machine at a cost of approximately one-fourth that of the job-lot pins.

An excellent example, although taken from the consumer's goods field, is that of the Campbell Soup Company which reduced the number of varieties of their products 89 per cent; and as a result the sales costs could be decreased 73 per cent while overhead fell 80 per cent—but sales volume increased 600 per cent. (See E. L. Bowers and R. H. Rowntree, "Economics for Engineers," p. 63, McGraw-Hill Book Company, 1931.)

parts for an old product be stocked, in what quantities, and so on? Obviously, the answer differs with circumstances.[10]

But this factor of obsolescence or supersession is not the only one that gives rise to more than one standard for the same type of product. It may be that special sizes are warranted for a large activity. It often happens that requirements of a customer necessitate departure from existing standards. This might be true for equipment sold to the Army or Navy, where specifications usually require a much higher set of standards than is ordinarily called for by the commercial purchaser. Possibly the manufacturer wishes to place the same type of product on the market in two or more different qualities. We are all familiar with this in the household equipment field and in the tires we buy for our automobiles. Sometimes, too, it is desired to set up several grades of a product below that grade which passes the main standards, and to sell these grades as seconds since they are yet quite usuable even though they are rejected from the first-class grade of product. Certainly, standards would have to exist for these lower grades, just as for the first-grade product. Many times, in a large organization with numerous plants, local plant conditions vary so widely that more than one standard of materials, processes, or product is most economical.

STANDARDIZATION OF PRODUCT

Any attempt at standardization of product disrupts several well-defined and diametrically opposed forces. In fact, standardization of product was achieved only when it was brought forcibly home to the manufacturers that if they did not hang together they would hang separately, as regards the degree of catering to customers' demands that each indulged in.

For example, suppose that the owner of a small job shop decides he needs a 4-horsepower motor. He calls up local representatives of several motor manufacturers, and is politely but firmly told that he can obtain a 3- or a 5-horsepower motor, but not a 4-horsepower motor. The shop owner blusters around and complains that the manufacturers are all allied against him. They have formed an alliance to make him

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[10] Consider a manufacturer of recording instruments. The design of the enclosure for some recording instrument is changed. Immediately standards are set up for the newly designed enclosure, but since many of the old-type enclosures are still on hand, the old standards are kept in force until all the older enclosures have passed into production—although part of the production is carried on with the new design immediately upon its inception. Furthermore, owing to a difference in mounting dimensions of the old and new instruments, it is necessary to furnish—and hence to maintain the standards of—the old-style enclosure for times when renewal of an enclosure is required for an old installation whose mounting features will not permit change-over to the new enclosure.

buy only what they want to supply—they have formed a conspiracy in restraint of trade.

That is one force, then, that works against standardization—consumer demand. The consumer often attempts to play two suppliers against each other in an effort to obtain a special product. Twenty or thirty years ago, if any buyer had demanded a 4-horsepower motor, some manufacturer would very probably have designed and built one for him. Then if another buyer wished a 4½-horsepower motor, that too would have been added to the motor manufacturer's line, and so on, ad infinitum. It is easy to see what an enormous and uneconomical line would soon be built up. Each manufacturer would have a large number of odd ratings, all of which required expensive tooling, design, set-up, and other charges. The result would soon have been chaos as far as the list of ratings went, and either a very high price per motor or bankruptcy for the manufacturer.

To counteract this tendency, the motor manufacturers soon discovered that they would of necessity have to agree among themselves as to the ratings of motors that would be offered for sale. A rational system of steps was worked out, based on one form or another of mathematical series. Now all large motor manufacturers have standardized on prices, on ratings, and to some extent on performance. The agency that has accomplished this standardization program is the National Electrical Manufacturers Association, familiarly known as "Nema."

Still another force is always working against standardization; manufacturer's initiative would be a good term for it. Every enterprising manufacturer desires to "get the jump" on competition. One of the simplest ways of doing this is by introducing a new rating, or size, or performance. To a certain extent this is desirable—it is progress. But, if carried too far, the result would inevitably be an uneconomically large line.

Standardization is economically desirable. Only when a line of products has been thoroughly standardized can it be put into mass production. And only by mass production can goods be produced cheaply and in great quantities. Almost any technical product bears this out.[11]

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[11] For instance, the modern automobile is turned out at a fraction of the cost of the early motor car, and is infinitely superior in performance and appearance. Most of us can recall the first "crystal sets" that retailed for $25. Now one can buy an excellent little portable radio that is immeasurably superior to the first hand-made sets, and that, being built by mass-production methods, sells for but a small part of the price asked for its predecessors. The electric refrigerator is right now in the process of being brought down in price by these methods of mass production. Even airplanes are beginning to show the effect of greater volume of production.

Amusing situations occur when a manufacturer attempts to supply what the customer wants, and yet do so economically. An example with which the author has had personal contact is that of a large manufacturer of precision equipment. The demand for this type of equipment is such as to justify building six, and only six, ratings. Yet the customers demand approximately twenty ratings, and, if this manufacturer is to get his share of the business, he must offer this number of ratings. He solved this problem very neatly by publishing a price list covering twenty different ratings, with prices graduated for each rating. When an order comes in for one item, he selects the one, from the six that he has built, that conforms most closely to the rating the customer desires. The nameplate is engraved with this rating, and the customer is happy. Obviously, some units are thus sold below cost, this loss being made up on the units that show a large margin of profit.

The difficulty arises when the same customer orders two machines of slightly different rating, and pays a price differential of, say, $100 for the higher rating. When he gets the machines, he finds that they are identical, except for the nameplate. Accusations fly, the customer insisting that he has been cheated. He does not realize that the situation has been brought on by his own unrelenting demand for ratings too close together to warrant the extra costs of building different units.

This situation will undoubtedly be remedied in a few years when the industry grows up and the activity increases. Then the manufacturers will find it to their best interests to cooperate in standardizing the ratings to be built, and to agree that no other ratings will be offered for sale. But only when the manufacturers offer a united front can this be done.

In selecting the sizes for a standard line, many factors must be considered. A few of these are:

1. Additional manufacturing costs of each added size or rating, due to tools, dies, jigs, etc.
2. Increased efficiency of a larger line, since each size will be closer to actual required rating.
3. Added customer appeal of a larger line.
4. Increased warehousing and similar expenses attendant to a larger line.

PREFERRED NUMBERS

Reference has been made several times in this chapter to the necessity for a logical series of sizes or ratings for use in standardization. One might naturally assume that the sizes would be chosen at

random by the designer. That is, the designers who first set up a line of, say, electric motors or light bulbs, would arbitrarily choose a number of sizes or ratings that looked as though they would meet present requirements. Then, as activity in motors or bulbs increased, sizes would be added whenever the demand warranted it.

Unfortunately, this was all too true. The engineer in one early motor manufacturing concern may have set up 1, 2, 7, 10, and 15 horsepower as their standard line of ratings. Another company's engineering department might just as readily have set up 1, 3, 5, 10, and 15 horsepower for their line of motors. Then when the demand warranted additional ratings, different manufacturers in all probability would choose additional ratings which were not exactly alike—but perhaps differing only by a fraction of a horsepower.

And so we see that, in designing any line of a product that gives the engineers freedom in the choice of sizes, the chances are strongly against different companies choosing the same series. Unless there is some guidance as to what ratings or sizes should be selected, various lines will show a wide spread. The result is, obviously, the antithesis of standardization. To the purchaser who wants to compare prices or performance of such a product offered by several manufacturers, nonstandardized lines are one gigantic "headache."

In recent years a movement has been under way in industry to set up a series of numbers whose usage would be preferred above all others. If such a series were to be widely adopted, a tremendous step forward would be made. It would create uniformity and interchangeability with their attendant advantages. Such a series of *preferred numbers* was recommended to industry for trial in practice by the American Standards Association in 1927. After study and revision, the system of "preferred numbers" [12] was approved by the association in 1936.

Preferred numbers are series of numbers which are to be used in preference to all others for the standardization of sizes, ratings, etc., of technical products.[13] Some of the applications for preferred numbers are:

> Ratings of machinery and apparatus in such units as horsepower, kilowatts, kilovolt-amperes, volts, amperes, gallons per unit of time, etc.

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[12] References: "Proposed American Standard Preferred Numbers," *American Machinist,* November 7, 1934, p. 773; "American Standard Preferred Numbers," *American Machinist,* July 29, 1936, p. 665, August 12, 1936, p. 701.

[13] References: "Standardizing Sizes and Ratings," R. E. Hellmund, *Electrical Engineering,* January, 1932, p. 14; "Standardization and Profits Aided by Preferred Numbers," R. E. Hellmund, *Electrical World,* August 18, 1934, p. 208.

Linear dimensions of importance, such as diameters, lengths, widths, thicknesses, areas, volumes, and weights.

Preferred numbers offer a logical and national series for standardization of such units. Preferred numbers are based on geometrical progression. That is, the first number of any series is taken as 10, and then the other numbers of the series are obtained by multiplying the first number or 10 by the constant factor for the series, which gives the next number following the base of 10, then repeating this with the resultant number for further numbers of the series. For three common series, the constants are derived as follows:

For the "5" series, constant $= \sqrt[5]{10} = 1.5849$
For the "10" series, constant $= \sqrt[10]{10} = 1.2589$
For the "20" series, constant $= \sqrt[20]{10} = 1.1220$

Using the rules given for obtaining the numbers of a series, we see that the "10" series is calculated as follows:

Base = 10 = first number of series.
$10 \times 1.2589 = 12.589$ or 12.5 as second number.
$12.589 \times 1.2589 = 15.81$ or 16 as third number.
And so on, for as far as one may wish to go.

For the "10" series, we therefore obtain a series of numbers or ratings in round numbers as follows:

10, 12.5, 16, 20, 25, 31.5, 40, 50, 63, 80

For the "20" series, the numbers progress thus:

10, 11.2, 12.5, 14, 16, 18, 20, 22.4, 25, etc.

All the above numbers are approximate to the theoretical series, none deviating more than 1.3 per cent.

As previously mentioned, the series that have been set as the preferred numbers series are all geometric series; that is, each number is larger than the preceding one by a fixed *percentage*. Since the purpose of preferred numbers is standardization, it is important that these series be used. The following are the series that have been officially approved and published as preferred numbers:

"5" series, which provides steps of 60% each.
"10" series, which provides steps of 25% each.
"20" series, which provides steps of 12% each.
"40" series, which provides steps of 6% each.
"80" series, which provides steps of 3% each.

In the event that it is absolutely impossible to use one of these series, because of an undesirable rate of increase in each case, supplementary series, such as are listed below, may be used in addition to the basic series:

Using every 3rd step in the 5 series gives 300% steps.
Using every 2nd step in the 5 series gives 150% steps.
Using every 3rd step in the 10 series gives 100% steps.
Using every ... step in the 5 series gives 60% steps.
Using every 3rd step in the 20 series gives 40% steps.
Using every ... step in the 10 series gives 25% steps.
Using every 3rd step in the 40 series gives 18% steps.
Using every ... step in the 20 series gives 12% steps.
Using every 3rd step in the 80 series gives 9% steps.
Using every ... step in the 40 series gives 6% steps.
Using every ... step in the 80 series gives 3% steps.

It has been recommended that all new designs should be based on preferred numbers. If this is done, subsequent standardization by national agencies or industries will be facilitated, and loss reduced to a minimum. Much difficulty with customers will be done away with if these numbers are used as a basis of all ratings and if everyone will cooperate in adhering to this rule. In many cases, however, where standards are already firmly established along other lines than the preferred numbers series, it may not prove economical to change, merely for the purpose of conforming to preferred numbers. But, as extensions are made to such systems, it is recommended that they be based on preferred numbers, so that eventually the preferred numbers system will take hold and predominate.

The purpose of these recommendations is to prevent the loss due to scrapped tools, dies, etc., where a national or industrial body causes all manufacturers of a particular product to revise all ratings in compliance with an adopted preferred numbers series. Even though preferred numbers are very desirable, it is readily seen how extensive would be the losses, design changes, tool scrappage, and the like, if every manufacturer were suddenly forced to assume ratings based on preferred numbers only, if he now has a complete line built up on ratings which do not conform. The only logical way of introduction of preferred numbers is to change over gradually so that the change will not serve to disrupt unduly the business and activity of manufacturers having established ratings not based on these series, and yet so that the series will eventually be 100 per cent predominant.

Important weights and dimensions should be preferred numbers. Addition and subtraction of preferred numbers does not usually give a preferred number, hence at least one diversion in interrelated values cannot be a preferred number. The multiplication and division of preferred numbers do give approximate preferred numbers, and hence if dimensions of a product are made preferred numbers, the area or volume will likewise follow preferred numbers.

Choice of the series and the corresponding steps to be adopted in establishing a product line is usually a very complicated procedure. Such factors as economy, performance, and utility must all be considered. If a small number of steps is used, then when the product is applied, in many cases, a larger size than is actually required must be used, which causes considerable waste as regards first cost, efficiency, and so on. Where costs increase but slowly with the size, this waste will not be so great; but where the opposite is true, the waste will be serious. The use of few steps is economical as regards tools, dies, set-up charges, stocks, and development, but lacks the appeal and efficiency of the larger line. Of course, no rule can be laid down to cover all products, the activity and nature of the product itself being the main determining factors. Ordinarily, in equipment of an electrical nature—and often it is equally true of other types of apparatus—efficiency is best if the machine operates at near its full-load rating, which means that if a line of few ratings is selected, some of the purchasers are bound to be operating their equipment at a point below maximum efficiency. All these facts must be carefully considered before deciding whether one's line is to consist of few or many ratings.

Preferred numbers are a very recent innovation in the field of standardization. It has already attracted much attention and interest, and gives promise of spreading throughout standardization of technical products. Many large industrial concerns are using preferred numbers in designing new lines and revising old ones. It does not seem unreasonable to expect that "standardization" will connote "preferred numbers" in the not-so-distant future.

Reference

Robins Fleming, "'Preferred Numbers' and the Civil Engineer," *Engineering News-Record,* June 11, 1936, p. 846.

STANDARDIZATION OF METHODS

A product that has been standardized as to quality, and made from materials which have been bought on rigid standards, lends itself

readily to standardization of each step in the various processes of manufacture. Process standardization is the adoption of the most economical and efficient method of performing each operation as discovered by previous experience.

To F. W. Taylor goes much of the credit for process standardization. Little attention was paid to his concept of standardizing a day's work, and his views were condemned as impractical. Taylor was the father of scientific management, and his summary made years ago cannot be improved upon now. In his paper entitled "Shop Management," presented before the American Society of Mechanical Engineers in 1903, he stated: "The adoption and maintenance of standard tools, fixtures and appliances down to the smallest item throughout the works and office, as well as the adoption of standard methods of doing all operations which are repeated, is a matter of importance, so that under similar conditions the same appliances and methods shall be used throughout the plant. This is an absolutely necessary preliminary to success in assigning daily tasks which are fair and which can be carried out with certainty."

In modern industry, tools and equipment have been highly standardized. With these standards as a basis, the time and motion study department has evolved data on which planning and standard costs are based. Each process to which a product is subjected has been studied, and a standard time set for accomplishing the process. The product has then been routed through each process in the most efficient manner possible, starting with the raw material and carrying it through until it enters a packing case at the shipping gate. Everything that is done or added to the product has been standardized, and the cost of each step accurately worked out.

With such a system in force, the quality of the finished product is likewise standardized. To insure this, the product is inspected as it undergoes each process, and must comply with predetermined standards at the end of each operation. Such inspections require standard units for comparison, standard methods, and in many cases standard gauges and similar devices.

Upon completion of the product, it is usually given certain tests to insure that its performance meets or exceeds certain standards. These tests insure that the product will operate properly and fulfill all guarantees of the manufacturer. Such tests are as fully standardized as any of the previous operations made on the product, or perhaps even more rigidly so. On an electric motor, the test may be for insulation, for temperature rise under load, or for efficiency and power factor. On a pump or fan, the test may ascertain whether the product

will deliver its rated load. Quietness of operation may be still another test of its performance. A new automobile may be given a severe road test along with efficiency tests on the motor, weather-resisting tests on the finish, etc. In a household electric refrigerator, the tests may be for speed of freezing, for safety and operation in case of leaks, and perhaps for quiet operation.

All these methodical procedures in the manufacture of a technical product may seem somewhat of a huge undertaking, but when one considers the high percentage of products that are good enough to pass final inspection in our many industrial plants, he begins to see how this constant uniformity of procedure acts as a continual check from the beginning to the end of a product's manufacturing process and that only by means of standard methods can losses and waste be made negligible, as they have been in many plants today. Defects and other non-uniformities are often caught before the product has gone very far along the process of completion, and at a stage where they may be corrected, hence creating a substantial saving both in labor and materials. It is only by standardized inspection methods after each operation, however, that such defects and non-uniformities can be caught at their sources.

One of the most important features of standard testing procedure is that it enables the comparison of products in many parts of the world. Only by bringing all products to a common testing location could such comparisons be made, were not standard procedures used. For instance, if a sample of steel in Los Angeles is to be compared in tensile strength with another steel in Pittsburgh, it is not necessary to send the two samples to a common testing place. So long as each test bar of steel is of exactly the same length, diameter, and design, and so long as similar testing apparatus is used to pull the bars apart in the two cities, the steel in Pittsburgh can be tested there and the Los Angeles steel can be tested in Los Angeles, and the results in pounds per square inch tensile strength can be compared with the assurance that the comparisons will be true ones. This is all possible only because of a highly standardized testing procedure that makes it possible to duplicate testing conditions at both points of testing. The results will be uniform and comparable so long as standardized procedure is followed in materials, methods of manufacture, methods of inspection, and methods of testing.

STANDARDIZING BODIES

Mention has already been made of "Nema," the electrical manufacturers' organization. "Nema" is but a member body of the main standards organization of America—The American Engineering Stand-

ards Committee. This organization was founded in 1917 by a joint meeting of special committees from the American Institute of Electrical Engineers, the American Institute of Mining Engineers, the American Society of Civil Engineers, the American Society of Mechanical Engineers, and the American Society for Testing Materials.

The American Engineering Standards Committee was established as a central committee for engineering and industrial standardization. It has broadened its activities until, today, it is the official representative of international standardization. It is primarily a body which formulates policies and also administers them. It does not delve into the technical side of standardization, but concerns itself with investigating the procedures followed by its sectional committees in the standards that they have formulated and are offering for approval.

A "sectional committee" is formed and goes to work on a particular standard only when some responsible body formally requests it. Advisory committees are sometimes set up to study the need for standardization along various lines of industry, and to suggest subjects for standardization. Once a field for standardization is decided upon, the American Engineering Standards Committee names a sponsor of the project, and the sponsor, in turn, names the sectional committee, subject to the approval of the A. E. S. C. The sponsor takes full responsibility for the work done by the sectional committee. This sectional committee is composed of representatives from the bodies that are interested in seeing the particular standards set up. The American Engineering Standards Committee sees that the representation is fairly distributed and that the members of these sectional committees are authoritative.

Three hundred and sixty-five organizations participate in the work of the American Engineering Standards Committee, among the more important national bodies being:

American Electric Railway Association.
American Institute of Architects.
American Institute of Electrical Engineers.
American Mining Congress.
American Institute of Mining and Metallurgical Engineers.
American Society of Mechanical Engineers.
American Society for Testing Materials.
American Light and Power Bodies—E.E.I., A.E.I.C.
Fire Protection Group—A.F.M.F.I., N.B.F.U., N.F.P.A., Underwriters' Laboratories.
National Electrical Manufacturers Association.[14]
Society of Automotive Engineers.

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[14] Reference: "Nema," D. Hayes Murphy, *Electrical Manufacturing*, May, 1938, p. 45.

Nineteen other countries besides the United States have established national bodies for standardization. Great Britain has a British Engineering Standards Association which corresponds to the American Engineering Standards Committee in the United States. Local committees are to be found in Canada, Australia, South Africa, India, and New Zealand.

Germany has a body known as the Deutscher Normenausschuss, which is made up of about five thousand industrial concerns and numerous engineering and industrial societies.

Two international organizations that deserve mention are the International Electrotechnical Commission and the International Commission on Illumination. The former has done much in the line of setting up international symbols, units, ratings, and so forth; it has twenty-four members among the nations. The latter concerns itself with standardizing nomenclature and standards.

The advantages of international standardization for units of measure, weight, etc., as well as for nomenclature, ratings, and performance of technical products, are self-evident. The difficulties are manifold. Too often nationalistically minded groups demand that their own nation's standards be accepted by all others, rather than that a true international standard be created. Any wholesale changing of standards must needs come gradually; a revolution in standards would be costly, owing to the terrific obsolescence of old apparatus and units which could not be adapted to the new standards.

Reference

J. Gaillard, "International Developments in Standardization Work; report on I. S. A. committee meetings, Budapest, September, 1936," *Industrial Standards,* December, 1936, p. 323.

CHAPTER VI

PRINCIPAL ELEMENTS OF COST

INTRODUCTION

When we analyze an industrial enterprise, we find a variety of costs necessary to its successful operation. Consider, for instance, a factory, and the bystander at once visualizes an outlay in expense for payroll to all employees, and for raw and semi-finished materials required in connection with the articles finally produced and marketed. Less obvious to the bystander are those expenses such as taxes, interest charges, patents and royalties, rents, insurance, and employee benefits of all sorts. Finally, of a yet more hidden nature, one finds costs which depend upon the passing of time and change in markets and methods, which we call, in its various forms, depreciation.

To illustrate all costs, Fig. 1 shows how, for the year 1937, each dollar received by a large manufacturer of equipment and machinery was divided as to items of expense. During this particular year a profit was made, a large share of which went to stockholders as dividends, and the remainder of which went into surplus account. During the year, roughly one-third of each dollar received was used for paying employees, one-third for the purchase of materials and supplies, and one-third for other items of cost, including profits.

If we examine these different items of cost, and consider how they will vary with the changes that take place in the volume of business done, we find that some items will have much greater variations than others. This has led to a segregation of cost items under the headings of "fixed costs" and "variable costs," which, though not entirely accurate as we shall see, serves as a practical basis of classification. It is important to fix in the mind of the reader that, in considering these various cost items, we refer not to variations in price per unit, but total cost to the company.

Analyzing the cost items in Fig. 1, we find that the total cost of materials purchased will vary quite definitely with the volume of business done. The total cost of wages and salaries, constituting payrolls, will also vary, although less variation will occur in connection

with the size of the payrolls for engineering, sales, administration, and general, than for manufacturing labor.

This particular company has no bonded indebtedness. If it had, interest would be distinctly an important item included in fixed costs.

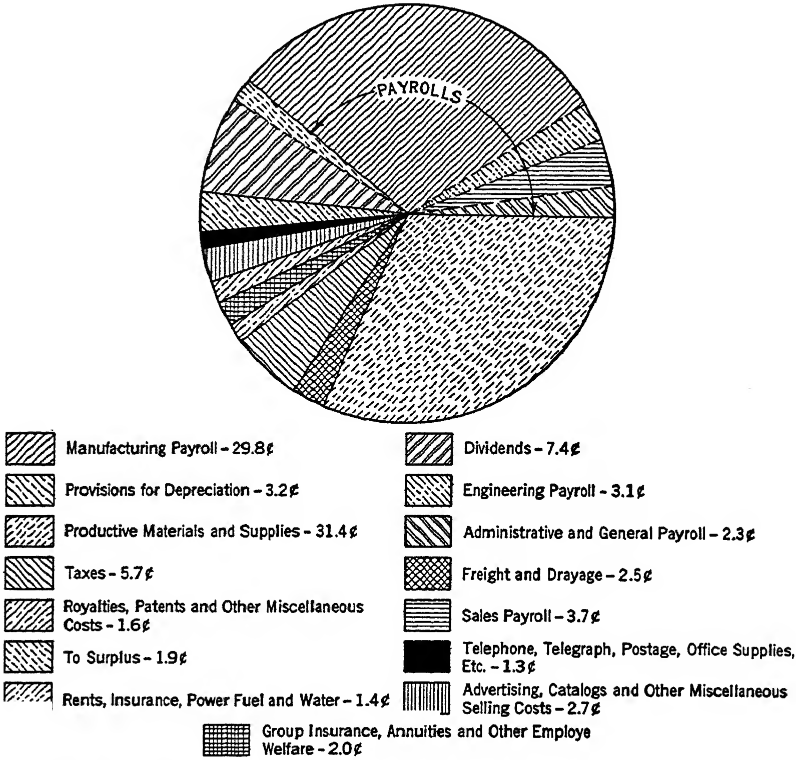

FIGURE 1. How each dollar, received from the sale of products by a large manufacturer of equipment and machinery during 1937, was divided as to items of expense.

If the reader will study each item of cost carefully, with the thought in mind as to how each item will vary with the volume of business done, a segregation can be made as follows:

Costs that are largely fixed:

Taxes.
Rents, insurance, power, fuel, and water.
Group insurance, annuities, and other employee welfare.
Royalties, patents and other miscellaneous costs.
Interest, if any.

Costs that are largely variable:

Freight and Drayage.
Payrolls.
Productive Materials and Supplies.
Advertising, Catalogues and other miscellaneous selling costs.
Telephone, Telegraph, Postage and Office Supplies.

In this particular year, this company earned a return, part of which was passed on to the stockholders in the form of dividends yielding them an interest on their investment, and part was assigned to surplus to make up for losses experienced in past years and to help provide for such contingencies in the future.

In this chapter, we will not include a discussion of the cost of paying employees, nor the cost of materials and supplies which go into the product itself or those used in its manufacture. These receive attention elsewhere. We will devote our attention to those costs of production which, to a considerable degree, are hidden, yet are none the less important.

THE EFFECT OF COSTS AND VOLUME ON PROFITS

We have pointed out that there has been a marked increase in the necessary investment on the part of most industrial companies in productive equipment, and also a decrease in the labor required to produce a large volume of output, owing to mechanized processes. Obviously, these changes, when we consider variations in the volume of business, will have an effect on earnings since they have increased the fixed charges to a remarkable degree, further augumented by such items as increased taxes. Such changed conditions have brought about an increased instability of profits.

Let us illustrate what takes place by comparing the effect of a variation in the volume of current business upon a manufacturing plant which is unmechanized, such as existed years ago, and a modern highly mechanized mass-production plant. Figure 2 shows the primitive or unmechanized plant, with little investment other than land and buildings; Fig. 3 shows the modern mass-production plant where the investment is largely in productive equipment with its correspondingly high fixed charges.

In Fig. 2, as the volume of business falls off, the total cost of labor and materials falls almost as rapidly, and the plant can continue to operate at a slowly decreasing profit under a very low load.

On the other hand, from Fig. 3 we see that, although the highly mechanized modern plant earns a high profit when running at full

capacity, as the volume of work falls off this profit rapidly diminishes and changes to an increasing loss on account of the relatively high fixed charges.

Instability is further engendered by the anxiety of management to avoid heavy losses by continuing to operate for the purpose of defraying as great a share of the fixed costs as possible. In this anxiety, there is a tendency to cut selling prices of the product, accumulate large stocks of finished products, and adopt unbusinesslike methods in order to attract sales volume temporarily—in fact, anything that will avoid the company's entering the area on the chart

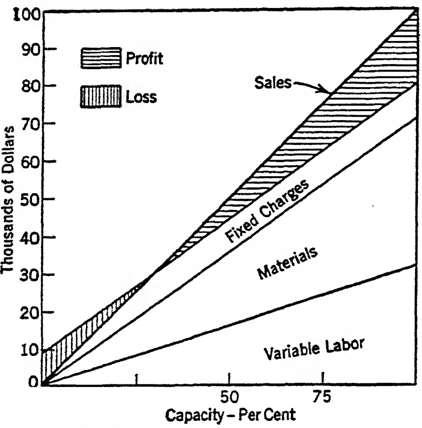

FIGURE 2.* Effect of costs and volume on profits in unmechanized plants.

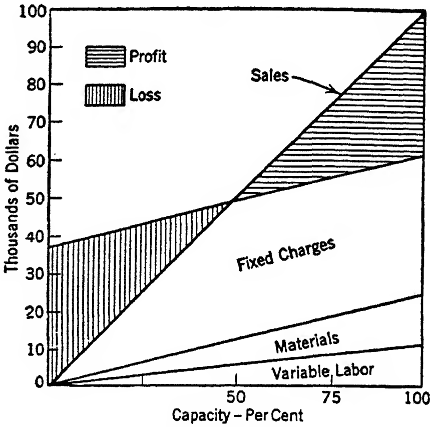

FIGURE 3.* Effect of costs and volume on profits in highly mechanized plants.

* Based on charts by W. H. Rastall, *Mechanical Engineering*, March, 1932, and reprinted in "Marketing Industrial Equipment," Bernard Lester, McGraw-Hill Book Co., Inc., New York, 1935, p. 22.

where losses mount so rapidly. Management feels that it cannot afford to shut the plant down on account of heavy losses, so it continues to operate to *avoid* as much loss as possible.

In a study of these charts, the reader will note that much less labor for an equal volume output is required in the highly mechanized plant than in the unmechanized plant. Also, that the cost of materials is usually less in the highly mechanized plant than in the unmechanized one, although this factor will vary with the kind of product made. In the case of much of the machinery made from metal, in the highly mechanized plant where mass production takes place, detailed attention is given to economy in design and the selection of materials.

For instance, punched parts may be substituted for cast parts at a great saving in material and cost when large quantities are required. Today, the designing engineer has at his disposal hundreds of alloys and plastics and complete information about each enabling him to apply them to his designs most economically.

TAXES[1]

No expense has attracted more attention, on the part of industrial enterprises, during recent years than the subject of taxes. This has been not only because of the increase in variety and total amount of taxes, but also because of the increased expense that has been necessary to carry on the legal and accounting work required to determine the nature of taxes to be paid and provide the necessary accounting procedure to comply with all taxation rules.

Taxes, chiefly, apply to property and are paid to government units, such as municipalities, counties, and states; but also apply to sales, inventories, and profits, and include tariffs and payments for the support of the national pension system. Each year has seen taxation more varied and complicated from the viewpoint of the industrial producer. No attempt will be made to analyze problems of taxation further, when we consider the many changes[2] that are taking place.

The industrial producer has not only been faced with paying taxes in greater variety and in greater amounts, but also with the costs of keeping abreast of tax legislation, keeping increasingly elaborate and more expensive records, and formulating tax reports.

RENT AND INSURANCE

Most large industrial enterprises own their own factory sites, buildings, and equipment. As we consider smaller companies, we find that many of them rent both factory site and buildings. Considerations as to the desirability of location and facilities, and also business activity throughout the district, as well as the state and suitability of the building itself, determine the rental rates charged. The availability of cheap labor, power, and transportation naturally affects rental rates, as do property values.

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[1] See also Chapter III, page 85.

[2] In 1929, 12 per cent of our national income was spent for taxes. From 1933 to 1937, 17.4 per cent of the national income went for taxes. This change represents a 45 per cent increase, and manufacturing industries paid for a large share of the total tax bill. For instance, one large automobile company's ascertainable tax bill in 1937 was $104,959,000 as compared with $63,150,000 in 1935.

From the viewpoint of industrial management, the payment of rent is the same as interest charges, and also involves depreciation which the owner must naturally stand.

The economic advantages of renting a factory site and factory buildings are these:

Renting is favored:

Where the capital of the existing company is limited.

Where manufacturing equipment and processes are simple, and require little in plant equipment.

Where the enterprise is more or less in the trial stage.

Where there is question as to ultimate desirability of plant location.

Where facilities are desirable for temporary operation, awaiting the completion of more definite plans.

Some industrial enterprises furnishing a form of public service pay on an annual basis for franchise rights, which is simply a fee paid for exclusive rights to render service.

Another form of rent is that paid by a mining company for lease of a property. The situation is somewhat different here, however, because as mining proceeds the supply of ore decreases, and those who rent do so for the single purpose of depleting the raw materials available. Great risks naturally occur, owing to common fluctuations in the price of mined products.

The value of protection against loss by fire and other insurable hazards is so well recognized that few who manage industrial enterprises fail to make use of it in connection with physical property of all sorts. Insurance rates depend upon a number of factors, such as location, construction, and moral risk. Often the property owner can obtain favorable rates by living up to certain restrictions and providing facilities which tend to reduce risks.

PATENTS AND ROYALTIES

Most companies providing technical products or services become involved, sooner or later, in matters relating to patents, licenses, and royalties. These usually relate to the product itself, or to processes of production, and have been treated elsewhere in this book.[3] Where the company takes out a license and pays a royalty for the right to manufacture and distribute a product, or use a process, such royalties become a definite expense item. Usually such expenses are based upon an annual fixed sum, or upon the quantity of items produced, or both.

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[3] See Chapter IX, page 240.

INTEREST

Many industrial companies, to provide working capital, borrow money, usually from financial institutions. Commonly, such loans take the form of bonded indebtedness, long-term loans secured by notes and collateral,[4] or short-time loans which may or may not be secured. Upon all of these, interest must be paid in accordance with the terms stipulated when the obligation occurs, the rate of which will be affected within certain limits by existing laws and by the financial integrity of the borrower. Interest expenses are, therefore, a fixed expense which must be met—otherwise the financial position of the borrower becomes adversely affected.[5]

EMPLOYEES' INSURANCE AND BENEFITS

Many forms of protection and benefits are now furnished employees, by most established industrial organizations, and the expense of these, in part at least, is borne by the employer. In some instances, laws for the benefit of employees provide protection and benefits, the expense of which must be borne, at least in part, by the employer. We find, therefore, that definite expenses exist, both of a compulsory and a voluntary nature, which must be met as an item of cost by each industrial enterprise, as fixed costs.

DEPRECIATION AND OBSOLESCENCE

Depreciation is a concept which we encounter in everyday life. Sometimes, depreciation strikes us very agreeably, for example, when we purchase an article that is "second-hand" or "shop-worn." Such articles, we discover, have "depreciated" in value simply because they have been used. Consequently, we can buy them more cheaply than if they were new.

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[4] Collateral is anything of value which can be assigned to, and is acceptable by, a lending agency as security for a loan. It may consist of stocks and bonds, goods in transit or storage, real estate mortgages, or an assignment of accounts receivable. Usually, in loans secured this way, the amount loaned is considerably less than the existing value of the collateral at the time the loan is made.

[5] It is interesting to note that, as of November 1, 1935, there were $2,129,000,000 in railway bonds in default of interest, or 16 per cent of the total railway funded debt. Public utility bonds in default totaled $673,500,000, and industrial bonds, $684,000,000. In 1929, the picture was much different, for railway bonds in default totaled only $98,800,000, while public utility and industrial bonds in default were $235,900,000 and $64,100,000, respectively.—*Wall Street Journal* data, December 19, 1935.

At other times, depreciation is not so pleasant—especially when we try to sell the automobile which we have used for many years. We suddenly discover that even though our car will give many miles more service, no one will pay more than a fraction of its original price.

If we ran our private financial affairs as does industry, automobile owners would consider depreciation as one item of cost in running a car. If we bought a car for $500, we should assume that each year it would depreciate or decrease in value by $100, and at the end of five years be entirely valueless. Hence, each year we would set aside $100 to form a depreciation reserve, and then, at the end of five years, possess the money with which to replace it with a new car. Or, if we wished to trade it in at the end of the third year, our depreciation reserve of $300, plus the theoretical scrap or trade-in value of $200, would purchase a new car.

To an engineer, in the study of economics, the principles which underlie depreciation in its various phases are highly important. It deals with varying values, elapsed time, known facts, and intangibles caused by outside influences. It applies to all industrial activity, and a practical consideration of it is necessary to the success of every enterprise.

DEPRECIATION DEFINED

Some authors, when referring to industrial depreciation, define it simply as "expired capital assets." That is, a machine tool that is being used in an industrial plant is considered a capital asset. Each year, this machine loses some of its original value, owing to use or to the mere expiration of time. So, each year part of the assets of the concern "expire," or become non-existent because of depreciation. Occasionally, a process is revolutionized or completely superseded by something new. Then the machines used in the old process may not be convertible for use in other processes, and hence depreciate to scrap value almost overnight. One of the most striking examples of this is in the automobile industry, where a radical change of body or other design renders thousands of dollars worth of tools worthless, or nearly so, in a very short length of time.

Other authors define depreciation in slightly different manners. In general terms, depreciation means a deterioration, or a lessening in value. When applied more specifically to industry, it has been defined as "the loss, arising from years of service, in the value of the investment in perishable property." [6]

[6] From R. B. Kester's "Depreciation," The Ronald Press Company, New York, 1924, p. 5.

Another author describes depreciation as the tangible or intangible loss in value which results from physical decay or from obsolescence or inadequacy. Still another definition is found in P. D. Leake's "Depreciation and Wasting Assets" (Sir Isaac Pitman & Sons, Ltd., London, 1920, p. 1). It reads:

> In its true commercial sense, the word "Depreciation" means fall in exchangeable value of wasting assets, computed on the basis of cost expired during the period of their use in seeking profits, increase of value, or other advantage.

The student will see that this last definition, although conveying essentially the same meaning as the others that have been given, looks at depreciation from an accounting point of view.

CAUSES OF DEPRECIATION

Now that we have a working knowledge of what depreciation actually *is*, let us investigate the factors that cause a capital asset to expire or diminish in value. The fundamental causes may be conveniently split up into three main divisions:

1. Physical depreciation.
2. Functional depreciation.
3. Contingent depreciation.

Physical Depreciation. Physical depreciation of a tangible asset is due to the wear and tear of use, to decrepitude or "old age," and to the diminution of mass. The wear and tear due to operation is usually the potent factor, but, of course, this factor differs with the asset under consideration. The wear and tear to which a machine is subjected depend largely on the original design, the maintenance service it receives, the degree to which it is loaded, the skill exercised in operation, and many similar factors.

Physical depreciation due to decrepitude or natural decay aptly describes the famous "Deacon's One Hoss Shay" from the poem by Oliver Wendell Holmes. This is the most outstanding example of "natural depreciation" on record. But this tendency is noticeable in all industry. As H. R. Hatfield expresses it in his book, "Modern Accounting" (D. Appleton and Co., New York, 1912, p. 121), "all machinery is on an irresistible march to the junk heap."

The third factor mentioned as being sometimes responsible for physical depreciation was diminution of mass. This is included by many authorities, and actually is important in certain phases of our

studies. The diminution of mass is a phase of such wasting assets as mines, oil and gas wells, and the extractive industries in general that become depleted by the very nature of their use. Obviously, this demands an entirely different treatment from that accorded general industrial depreciation.

Functional Depreciation. Turning now to functional depreciation, we find that this term covers inadequacy, obsolescence, supersession, and the acceptance factor. It indicates a decrease in the worth or the service value of an asset, due to these various causes. The asset becomes unable to perform its proper function for other reasons than those of physical failings.

As an example of inadequacy, the machine or other asset becomes unable to fulfill the demands of a growing business or to meet changes caused by new developments. In this latter case, the asset is said to have been superseded. The rapidly increasing usage of a product will often necessitate supersession of the old machinery used in the manufacture,[7] if the concern is to take advantage of the expanding market. Inadequacy may be brought about by such internal forces as changes in policy, engineering economy motives,[8] and unexpected expansion. The first cause, that of policy, is often the result of changed ownership, changed management, or mergers. As for economy, consider a small plant installed to meet the requirements of a young community or a new product. Even though expansion is anticipated, it may still be economical to start with a small plant that will be scrapped later on. An unexpected development may conceivably make an entire plant inadequate to meet the expanding demand.

External forces frequently give rise to inadequacy. The public utilities are sometimes affected by legislation which requires them to make expensive changes in their distribution systems. Fire, sanitation, and safety[9] ordinances many times force the entrepreneur to discard equipment before it has rounded out its service life.

[7] An old New England company has built steam engines for many years. Steam turbines and internal-combustion engines have largely superseded this product. Specialized tools, dies, and fixtures for the manufacture of the steam engines are now obsolete.

[8] A large automobile manufacturer in Michigan in recent years changed over its factory power system from direct to alternating current. A large number of direct-current motors had to be replaced; their value depreciated more rapidly than otherwise for there was no longer a use for them, and they had to be disposed of at a material sacrifice.

[9] Many passenger and freight elevators and some classes of machine tools have had to be replaced, not because they were worn out, but because they presented too great a risk to life and limb.

Obsolescence is another big factor in functional depreciation. It is brought about by external and internal forces similar to those mentioned as causing inadequacy and supersession. Changes in processes, more efficient machinery, new methods of production—all these tend to make existing assets become obsolete. The obsolescence of some machine tools in the automotive industry has been previously mentioned. Obsolescence, in these examples, may be so great that it becomes an appreciable cost factor. A $20,000 machine tool that has a service life of twenty years may become obsolete in five years because a better design becomes available.

Changes in customer interests relating to appearance, as exemplified by form, color, shape, and finish, have done much to make previous designs of equipment obsolete.

Contingent Depreciation. A third major cause of depreciation has been denoted by the word "contingent." This term covers such events as those which have happened and may happen again—as well as those that are looked upon as being, to a degree, inevitable. Provision is usually made for these factors under the heading of "depreciation" in order that their costs may be more evenly distributed from year to year.

Such losses may be due to accident, negligence, structural defects, or the elements. For instance, a machinery builder may, in the original design, fail to provide a sufficiently large bearing for one particular part of the machine. Machines thus built and put in service give abnormal trouble in this respect, and consequently must be depreciated more rapidly than otherwise. Or, again, the substation of an electric power company is flooded by unanticipated high water, or injured by fire, and a large share or all of the value of the equipment may be destroyed.

Insurance premiums covering some classes of loss take the place of depreciation reserves in some industrial concerns.

RATE OF DEPRECIATION

No matter what the equipment may be, upon which one wishes to determine the rate of depreciation, certain factors such as those mentioned must be carefully weighed in order to arrive at a logical and correct rate of depreciation. Not only is it most important to be able to recognize all the existing facts that contribute to the depreciation of the equipment, but it is also important that we know what method of depreciating calculations we should employ for each particular case.

The accountant may set up his depreciation rates in line with any one of a large number of systems, as will be described in detail later in this chapter. In considering a factory building, the accountant may assume that a modern fireproof building will last 40 years, and consequently he charges off the depreciation on the building at the rate of 2.5 per cent per annum. For a machine tool, the rate of depreciation is usually much greater, because there are more factors which may destroy value with the passing of time. We will mention a few of the factors that cause this variation in the rate of depreciation.

Normal operating conditions have a close correlation with the rate of depreciation. Abrasive dust, for instance, in the atmosphere surrounding the machine may definitely affect its service life, as may temperature and humidity. Also the skill of the operator usually affects the life of equipment, as do the intensity and duration of operation.

The repair or maintenance policy of the plant has much to do with the service life of machines and structures. A concern whose policy it is to make repairs only after a breakdown has occurred will experience a higher depreciation rate than one that follows a policy of making regular tests and inspections, and catches probable causes of failure before their occurrence.

One further factor in determining the depreciation rate is versatility in the use of the machine or structure. If it can be adapted to another use after the need for the service for which it was originally intended no longer exists, the value of the machine or structure, in a measure, is preserved.

Let us summarize the leading factors that influence the rate of depreciation of equipment. For a piece of apparatus, they are as follows:

1. Operating surroundings,[10] such as dust, dirt, vibration, and extremes in temperature and humidity.
2. Continuity of operation, or the number of hours per day or week in which the apparatus operates.
3. Service factors,[11] such as severe overloads or unusual demands.
4. The care and maintenance which the apparatus receives.

[10] Heat exchangers in refineries, and machinery in a coal mine, are subjected to extremely severe operating conditions.

[11] During the World War, much machine tool equipment used for making shells received abnormally severe service and depreciated very rapidly.

5. The progress of the art as related to the type of design[12] which the machine represents; if improved machines become quickly available, the existing old machine loses its value more rapidly.
6. The price level of new apparatus of a similar type.
7. Changing nature[13] of service required of the apparatus.
8. Contingent risks applying to the use of the equipment.

References

C. V. Castle, "Economic Obsolescence of Industrial Equipment," *Mill and Factory*, January, 1938, p. 85.

Paul T. Norton, Jr., "Profits May Be Unreal if Depreciation Rates Are Inadequate," *Iron Age*, March 9, 1939, p. 72.

FURTHER DEFINITIONS

Before going further into the subject of depreciation, which is of particular importance in our study of economics, there are several additional definitions or concepts worthy of discussion and of consequence in the work that is to follow. Among these are *effective, actual,* and *theoretical depreciation; depreciation versus depletion;* and *repairs versus renewals.*

Frequently, several of these causes of depreciation which we have outlined may be at work simultaneously, but never is their effect cumulative. For example, it might be conceivably estimated that, on a certain asset, obsolescence will be complete in 15 years, inadequacy in 13, and physical depreciation in 10 years. It is not difficult to understand that, for such an asset, the physical factor is the effective one, its estimated duration of 10 years being the "effective depreciation."

Another term commonly used by engineers and accountants is *actual* depreciation. Actual depreciation is the difference between the value of a piece of equipment or a structure when new and that at the present time. It is the decrease in value from the date of installation to the present moment. And the value at the present moment is the amount for which it would sell to an existing market.

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[12] Air conditioning, as a class of apparatus, is quite new, and is undergoing continual improvement. Undoubtedly, much equipment that has been supplied will depreciate rather rapidly. This applies also to airplanes. Reference: "Quick Turnover of Equipment Brings Profits," Frederick A. Smith, *Mill and Factory*, February, 1938, p. 54.

[13] Many types of machine tools for cutting metals became obsolete rather rapidly as it was discovered that the work they were doing could be done more cheaply and better by certain grinding machines.

Theoretical depreciation looks at an asset from the viewpoint of financing the depreciation. It is a concept with which the accountant is interested, since it concerns itself with financing the loss in value throughout service life of the equipment, rather than establishing its value at any point during its life.

The curves of Fig. 4 show the difference between actual and theoretical depreciation. Curves 1 and 4 show the actual depreciation; curves 2 and 3 show the theoretical. Curve 1 is the depreciation from the viewpoint of saleability; curve 4 is from the point of view of

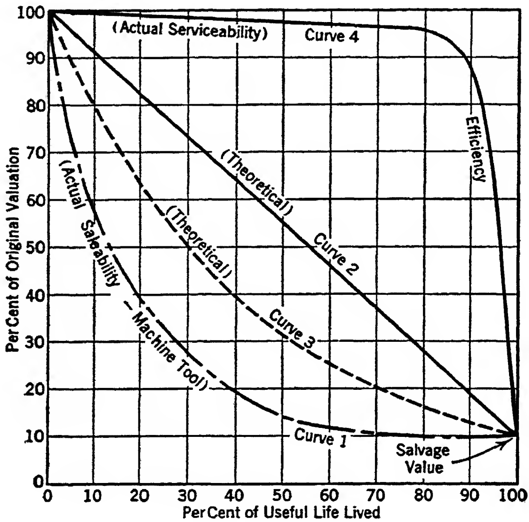

FIGURE 4. Actual and theoretical depreciation.

serviceability. The two theoretical curves represent various methods of calculating depreciation, as discussed later.

The distinction between *depreciation* and *depletion* is a simple concept that is occasionally overlooked. Depletion is a form of depreciation applicable to the extractive industries. A coal mine is depleted as the coal is removed from the veins. This asset cannot be replaced out of a depreciation reserve, and, once it is exhausted, the concern having to do with it is finished, unless, of course, another source is located. The difference between depletion and the depreciation of the capital assets of a manufacturing company is, therefore, quite obvious.

One differentiation remains, and that is between *repairs* and *renewals*. "Repairs" cover all current expenditures made frequently

on the upkeep of the capital assets without renewing any substantial part, and are usually calculated on an annual basis. On the other hand, "renewals" are expenditures incurred usually at longer intervals, and tending to prolong the life of the asset beyond its average length.

SOME ASPECTS OF DEPRECIATION CALCULATIONS

The calculation of depreciation may be approached from various angles, all depending on the objective of the study. The engineer making an economy study will, in all probability, regard his depreciation calculations differently from the accountant who is keeping the books of the company. Depreciation, as a matter of financial policy, is vastly different from the study of depreciation for the valuation of the assets of a public utility.

We find that it is necessary, in the study of depreciation calculations, to take up the subject from four angles:

1. Engineering economy studies.
2. Accounting.
3. Financial policies.
4. Valuation.

The critical use of depreciation calculations in economy studies is, to the engineer, the most important of these four approaches. It has innumerable complications and ramifications, and the best that can be done in this volume is to cite a few examples representative of the general trend.

Engineering Studies

In calculating depreciation, engineers often divide the first cost minus the salvage value by the estimated years in life. This is a simple method, easily understood. It leaves the question of interest out of the picture, which may or may not be a good thing. If the estimates of length of life and of salvage value are at all uncertain, this method will doubtless give as good results as the more complicated ones.

Let us suppose that we are engineers considering the purchase of a $10,000 machine tool. We estimate its life to be 10 years and its salvage value $1000 at the end of that time. Let us plot this curve of depreciation, assuming that the annual depreciation will be equal to the purchase price, or $10,000 minus the scrap value—$1000—all divided by the estimated life of the tool of 10 years. Our annual depreciation is hence $900 and our tool depreciates in a straight line as

in Fig. 5. But what will the efficiency of this machine be over the 10-year period, we might ask? If the efficiency declines as rapidly as our theoretical depreciation, at the end of 5 years the machine will be a little better than 50 per cent efficient. Obviously this machine would be unprofitable, for it would need replacement in a few years before it passes, say, the 70 or 80 per cent mark.

However, we all know that the average machine tool maintains its efficiency within reasonable limits until near the end of its service life, at which time the efficiency drops rapidly. We can plot, then, our machine efficiency as shown by the dotted line on Fig. 5. By this we

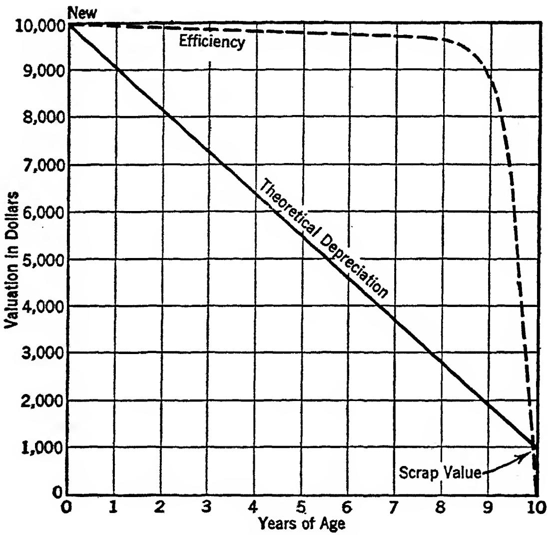

FIGURE 5. Theoretical depreciation vs. the efficiency of a machine tool.

see that our efficiency and depreciation vary widely, and it would be profitable to use the machine for 9 or 10 years.

The great objection raised to this method of calculating depreciation is that it differs considerably from the actual depreciation. Curve 1 of Fig. 4, page 150, shows actual depreciation from the standpoint of saleability, and we see that it is very great in the first few years. If the machine were sold at the end of the fifth year, a loss would be sustained. Although this is true, and will appear entirely unreasonable to us, the answer is that the engineer wants a quick method for calculating depreciation with an eye to the future replacement of the machine and not to its future sale.

Depreciation Accounting

The method of depreciation we have just discussed, frequently termed the "straight-line method," is the most widely used of all the methods because of its great simplicity. Many others are familiar to those with an accounting background, and it seems wise to review them here.

Accountants recognize four or more main divisions of depreciation methods. These are:

1. Proportional methods.
2. Uniformly diminishing amounts methods.
3. Compound-interest methods.
4. Miscellaneous methods.

Proportional Methods. Under the proportional methods of calculating depreciation, we find, first of all, the "straight-line," which has already been discussed and commended for its simplicity, although it was noted to depart from the actual depreciation curve.

The "working-hours" method gives the life of the asset in working hours rather than years or months. Thus, a machine will be said to have a service life of 10,000 working hours rather than five years, this being the only difference from the conventional straight-line system. It has the advantage of assigning the costs of depreciation more equitably to each unit of the product. It has the disadvantage of added complexity, and may not give a true picture if the machine is used for various operations with inequalities in upkeep, or if used beyond capacity for some operations.

Another proportional method very similar to the working hours is the "service-output" method. Here the life of a machine or structure is in terms of quantity of output, such as cubic feet of air through an air filter. When applicable, this method may give the most equitable allocation of depreciation costs. It is rarely used in general industry because of its complexity, but in respect to a mine, quarry, or other wasting asset, it is an invaluable method.

The last proportional method is commonly termed the "composite life" method. Its distinction is the treatment of depreciation on the plant as a whole. The *mean* life of the plant is calculated by "weighting" the life of each asset to give a true average. Its complexity is manifest even to the uninitiated, and it is rarely used except as an occasional check on other methods.

Reference

Maurice R. Scharff, "Depreciation Accounting Problems," *Edison Electrical Institute Bulletin*, December, 1937, p. 496.

The Uniformly Diminishing Amounts Methods. The proportional methods all calculated the periodic depreciation as a proportional part of a fixed basis value of the asset. The "uniformly diminishing amounts methods" differ from the proportional in that either the percentage rate or the basic value varies for each depreciation estimate. If the percentage is fixed, the base is varying; and if the base is held constant, the percentage varies. The two subdivisions under this method are:

1. The fixed percentage of diminishing value method.
2. The sum of expected life periods method.

In the first method, the fixed percentage of diminishing value, the depreciation rate is constant but the book value of the asset varies. That is, if the depreciation rate is set at 10 per cent and the initial value of the asset is \$100, the depreciation for the first year becomes \$10, leaving a base value of \$90. The second year shows a depreciation of \$9, with a new base then of \$81, and so forth. Obviously this is an infinite series, and zero valuation will never quite be reached.

Reduced to a formula, this method may be expressed as:

$$d = 1 - \frac{\text{Scrap value}}{\text{Cost}}$$

where d = rate of depreciation.
n = length of service life.

For example, let us calculate the rate of depreciation on the machine tool previously mentioned that cost \$10,000, had a service life of 10 years, and could be scrapped for \$1000.

$$d = 1 - \sqrt[n]{\frac{\$1000}{\$10{,}000}} = 1 - \sqrt[10]{0.1}$$

$$d = 1 - 0.79433$$

$$= 20.57 \text{ per cent depreciation per year}$$

The "sum of the expected life periods method" holds the base fixed but varies the percentage. For example, an asset with an expected 10-year life like the machine tool above has a life term of $10 + 9 + 8 + 7 + 6 + 5 + 4 + 3 + 2 + 1$ or 55 years. Then the depreciation rate

will become 10/55 of \$9000 for the tool above for the first year, 9/55 × \$9000 for the second year, etc., until scrap value is reached at the end of 10 years' life.

These two methods have the great disadvantage of complexity, and are difficult to apply accurately. They put the greater depreciation charges in the earlier years, and thus approximate the actual depreciation curve more closely than the proportional methods.

Compound Interest Method. This method marks a radical departure from the previous two in that it uses compound interest to determine the amount of periodic depreciation. The two methods falling in this category are:—

1. Sinking fund method.
2. Annuity method.

The "sinking fund" method calculates the sum of money which, when placed at compound interest, will accumulate to an amount equal to the total depreciation of the asset for the same period of time. To express it mathematically:

$$S = \frac{(\text{Cost} - \text{Scrap value})}{I^n - 1}\, i$$

where S = the sum which must be put away annually.
i = interest rate.
I = 100% + i.
n = service life of the equipment.

Taking again the example we have been using of the \$10,000 machine tool and assuming an interest rate of 5 per cent, we calculate the annual sum which must be placed on interest in order to accumulate an amount equal to the total depreciation of the asset, or \$9000 in 10 years:

$$S = \frac{(\$10{,}000 - \$1000)}{1.05^{10} - 1} \times 0.05$$

$$S = \$715.42 \text{ per year}$$

This method is to be preferred to a haphazard depreciation system, since it will write off the depreciation during the life of the asset. Much is claimed for it in the way of equitable distribution, but some authorities discount these supposed advantages.

The "annuity" method adds, to the sinking fund method's periodic depreciation charge, the interest on the periodic appraised value of the asset. This is in effect charging the product interest on the capital invested in each asset. Its object is to determine a periodic charge

to cover not only depreciation but also the interest which has been added to the value of the asset during the same period.

Mathematically, the annuity method is expressible as follows:

$$D_p = \frac{(\text{Cost} \times I^n - \text{Scrap value})}{I^n - 1}\, i$$

where D_p is the periodic depreciation charge, and the other symbols are as previously noted. In the example we have carried through by all other methods, this charge becomes:

$$D_p = \frac{(\$10{,}000 \times 1.05^{10} - \$1000)}{1.05^{10} - 1}$$

$$D_p = \$1215.42$$

which is the amount that must each year be allowed in order to give a return of 5 per cent on the existing investment and at the same time reduce this investment to scrap value at the end of 10 years. It can readily be seen that, since the investment gradually comes down, the interest earned hence also decreases, with the result that the theoretical depreciation increases year by year.

This method has the same criticisms as the sinking fund method. In addition, the principle of charging interest on the depreciated asset has been roundly condemned by many authorities.

Miscellaneous Methods. There are several other methods which are so rarely used as to make them scarcely worthy of mention. None of them is satisfactory in general industry.

One such method is the "maintenance" method which charges off a periodic amount for depreciation that is equal to the cost of maintenance for the same period. It thus gives an irregular depreciation charge, and is theoretically unsound.

Still another method, the "appraisal" method, deposits the difference between physical appraisals at periodic intervals as the depreciation. Its weakness lies in the impossibility of making accurate appraisals at such short intervals as one year.

The last miscellaneous method is that of "gross earnings." In this method, the depreciation estimate is based on the period's gross earnings. In theory, the method is unsound, although in practice it is occasionally workable.

Reference

Caldwell, "What a Shop Executive Should Know about Depreciation," *Machinery*, November, 1937, p. 166.

APPRAISAL OF VARIOUS METHODS OF CALCULATING DEPRECIATION

There is no one perfect method of calculating depreciation. The choice depends on the purpose of the depreciation study, the asset under consideration, the engineer or accountant, and other factors. Some authorities say that a depreciation system should approximate the actual depreciation; i.e., the heaviest depreciation should be in the early years of the service life of an asset. They claim that this is true, since repairs are greatest in the later years of the asset's life,

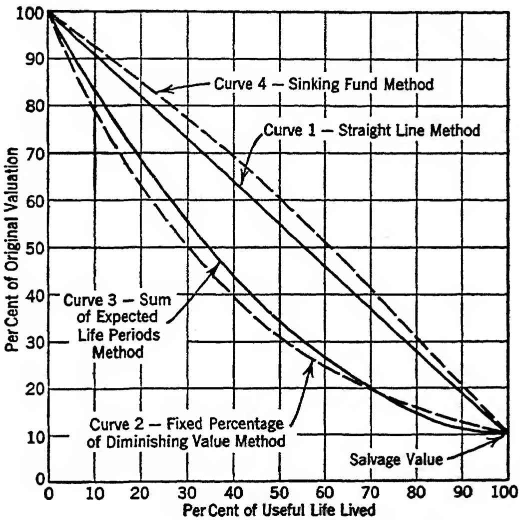

FIGURE 6. Results obtained from the various methods of calculating depreciation.

and hence the depreciation charge should be lighter then in order to keep the charges constant. If this is so, such methods as the straight line will place an unjust burden on the latter years of the life of an asset.

Generalities are impossible. In some cases, simplicity is the governing factor; in others, conformity to the actual depreciation curve. When choosing the method of calculating depreciation, the engineer must know the advantages and disadvantages of the various methods so that he can apply the one that best fits the circumstances.

From the four curves of Fig. 6 we see the results, as actually calculated, by each of the more important depreciation methods. This figure serves as a guide in determining which method to choose in any

particular case. It will be noticed that these curves are all on a basis of a life expectancy of the equipment of 10 years, and a salvage value at the end of that time equal to 10 per cent of the original cost.

Reference

E. A. Saliers, "Inadequate Depreciation Methods," *Accounting Review*, September, 1937, p. 303.

FINANCIAL POLICIES

Thus far, we have been concerned with what depreciation is and how it may be calculated in a number of different ways by both engineer and accountant. But just as important as determining the rate of depreciation is the *provision* that a company makes to take care of depreciation. The engineer frequently fails to distinguish between a depreciation "reserve" and a depreciation "fund," and becomes confused as to the way depreciation appears on the plant ledger.

The confusion between reserves and funds is widespread. Sometimes these terms are used not only loosely, but even interchangeably. In the face of this, it is wise for us to get the distinction firmly in mind.

Accounting practice holds that assets must be maintained intact, for the good of the enterprise. Hence, funds for future replacement must be set up out of the income of the business. The depreciation *reserve* is an indication of the sum that is necessary for such replacements, and prevents the distribution of this sum as profits to the stockholders. But the depreciation *reserve* does not actually set the money apart and earmark it. That must be accomplished by distinct entries, known as the depreciation *fund.*

Thus, we see that the depreciation reserve retains sufficient funds to take care of depreciation, but does not set these funds apart to be used for any specific purpose. If the company desires a distinct fund for depreciation, a sum of money set apart for the one purpose only, then it must credit cash as an additional step, and charge the depreciation fund with the amount of the fund. This sets up a special account that is for depreciation only.

The manner of entering depreciation charges on the books is an entirely different matter from the methods of determining it and the theories behind these methods. At the close of each fiscal period, depreciation charges are, by some companies, manipulated to remedy any discrepancies between the book accounts and the actual values.

The way in which the asset will be depreciated is dependent on the nature of the asset itself.[14]

The manner in which these charges appear on the books can be summarized thus:

1. The book values are written down to the actual values, carrying over the amount written off to the profit and loss account, and
2. A fund is provided to replace the assets as they wear out.

A company which is in the throes of expansion would probably be unwise to set up a depreciation *fund*, for this would mean the investment of money at low interest rates, and then borrowing money at a presumably higher rate of interest to finance the expansion.

Actual practice differs among large American industrial concerns. Few carry special depreciation funds, although many show depreciation reserves as liabilities or as deductions from assets. The creation of depreciation funds has been rejected by the Interstate Commerce Commission as being unsuited to railroad accounting.

A recent trade-paper article by a machine tool salesman throws an interesting sidelight on this. This particular salesman had been working unsuccessfully to sell his line of machine tools to an industry notorious for its antiquated shops. All the concerns he visited carried a depreciation reserve on their books and acknowledged the importance of maintaining their assets intact. But the executives of these companies—all to a man—swore that the book entries for depreciation were mere figments of their accountants' imaginations, and that there was no actual cash available to replace the obsolete machine tools. Consequently, few sales were made because no funds were available, although the books of many companies indicated differently.

References

"An Eye to the Depreciation Reserve," *Engineering and Mining Journal*, April, 1937, p. 178.

W. P. Kirk, "The Purchase of New Machinery and Equipment," *Society for the Advancement of Management Journal*, September, 1937, p. 154.

[14] For instance, a company manufacturing metal parts which required electroplating and then buffing, found that electroplating equipment manufacturers had suddenly put on the market plating machinery which plated these parts with a bright finish. The buffing machines were no longer required, and so were disposed of at a heavy sacrifice long before they were worn out. This represented a loss, for they were sold at less than the depreciated value, and consequently had to be charged off on the company books.

DEPRECIATION AS A FACTOR IN VALUATION

Thus far, we have viewed depreciation as a basis by which we can retire machinery or structures and get new ones in their places. There is still another phase of depreciation that is just as useful and just as important, however, and that is the use of depreciation in the field of evaluation of property, equipment, and industries.

The engineer often finds himself up against the problem of evaluating business concerns of various types—from public utilities to ice-cream factories. The purpose of these evaluations may be any of the following:

Rate making for public utilities.
Purchase of an industrial property or public utility.
Taxation of an industry or utility.
Capitalization of an industry or utility.

The problem of valuation is one of the most difficult and bewildering ever to confront the engineer. There is considerable diversity of opinion among engineers, accountants, and business men as to what constitutes a fair valuation. There have been many court decisions, some of them conflicting, as to what factors should be considered in evaluation of a public utility—the railroads being a great "problem child." For instance, today we may hear that the total valuation of all the American railroads is 26 billion dollars, while again tomorrow we may hear, from just as reliable a source, that this valuation is now 15 billion dollars.

A good many years ago, a traction company was organized in a certain small eastern city to build and operate horse-car lines. The company was conservative and sound, and kept its property in excellent condition, by systematic maintenance. With the advent of the electric trolley, the horse-cars were scrapped and new electrical equipment installed, but in time the even keener competition of the gas bus had made the operation of the trolley cars unprofitable. The utility saw bankruptcy ahead, so they employed an engineer to evaluate their property. He did this, first by taking the original cost of the property, depreciating it, and then correcting for price level; and secondly, by estimating the cost of reproducing the existing property. Armed with this impartial survey of their assets, the traction company's officials offered to sell their property to the municipal government at the engineer's evaluation. The municipal fathers laughed at the offer, and

said they would not take the property if it were given to them. This seemed an unreasonable attitude, since the rails, roadbed, overhead lines, and rolling stock were all in excellent shape. But the traction company was unsuccessful in its attempt to find a buyer, and eventually the company was forced to spend $10,000 to have the tracks taken up and the streets repaved.

This story of an actual happening not so long ago is an excellent illustration of what the engineer is up against in evaluations. It must always be kept in mind that, in evaluation work of any kind, there is, first, the problem of physical property evalution, and secondly, the problem of intangible factors, such as future earning power.

Physical property may be evaluated by several recognized methods, which are:

1. Cost of reproduction method.
2. Cost of reproduction less depreciation method.
3. Original cost method.
4. Original cost less depreciation method.
5. Original cost less depreciation corrected for price level method.

A study must be made of the many intangible factors that may or may not be reducible to a dollars-and-cents basis. It was these intangibles in the case of the traction company that threw the calculations completely out of reason. These intangibles may be:

1. Intangible property franchises, patent rights, trade marks, and the like.
2. Changing rates of return in the investment, brought on by such external factors as:
   - Changing availability of other forms of service.
   - Competition in the same form of service.
   - Obsolescence due to new processes and revolutionary changes in the industry or service.

All these factors and many others must be considered in making a correct valuation of any industry. Many industrial concerns can be fairly evaluated without considering anything but the tangible property. In rate making for a utility, the intangible factors are so important and so difficult that no arbitrary method can be set for evaluating. The many court decisions handed down on the evaluation of railroads, from the case of Smyth *vs.* Ames (169 U S 466) on down to the present, form interesting and at times entertaining reading.

Chapter References

W. J. Vatter, "Depreciation Methods of American Industrial Corporations," *Journal of Business*, April, 1937, p. 126.

P. T. Norton, Jr., "Rethinking Depreciation and Obsolescence," *Foundry*, August, 1937, p. 28.

"Obsolete Equipment a Drag on Industrial Recovery," *Manufacturing Record*, April, 1937, p. 46.

CHAPTER VII

STATISTICAL AND ACCOUNTING METHODS

INTRODUCTION

In this chapter, we are going to consider business statistics and engineering statistics, as well as established statistical plans for future performance, which we term budgets.

Statistics are necessary to all forms of efficient procedure, whether such procedure relates to economic or technical decisions. Unless such procedure is based upon facts which are reliable, related to the existing purpose, and arranged in such a way as to be useful, no dependence can be placed in results to be obtained, or plans based upon such results.

Business statistics embrace all matters relating to economic performance: bookkeeping, balance sheets, cost records, statements, and all classes of business records. We can well imagine how purposeless it would be if no business data were available upon a manufacturing enterprise or a construction project. No information would be available to show whether profits or losses occurred, and nothing at hand upon which to base subsequent plans and action.

Engineering statistics relate to technical performance of a product or service. One can well imagine how futile the work of a designing engineer would be if he had no data upon which to base a design, and no performance records upon designs which he had created.

In the study of this chapter, careful attention should be given to the two classes of statistics elaborated upon—business and engineering—and the similarities and differences of the two should be noted. The evolution of engineering statistics has been interesting but complex, but the fundamentals are not difficult to grasp if the real purpose of engineering statistics is kept in mind.

BUSINESS STATISTICS

The Need for Statistics and Data. Business statistics are necessary today for every phase of activity of an industrial enterprise. With the profit motive dominant, the fundamental purposes of business statistics

are to show an existing condition of profit or loss, and also to furnish data upon which to base operations which will lead to increased profit.

In illustrating the importance of business statistics to a going concern, let us consider a few cases where business statistics assume vital importance.

One manufacturer builds and sells four different classes of product, all of which are well established. They are not closely related to one another, in respect to the purchasing market or to process of manufacture. Upon the basis of several years of operation, reliable statistical information indicates that one of the lines of product shows a consistent loss, though the operations of the company, as a whole, show a profit. There appears to be little opportunity for expanding the volume of business for this particular product. After due consideration, the management of this company decides to discontinue the manufacture of this particular product. With the added factory facilities and greater opportunities for concentration, this company is able to make a greater profit on each of the three remaining lines of product, and thus make a larger overall profit. Without definite statistical information upon operations and markets relating to the particular product which was dropped, it would have been impossible to reach this decision in an intelligent way.

The management of another company is impressed with its low profits and, on the basis of statistical information upon the ratio of the value of products made and capital necessary, is further impressed with the fact that this capital is not turned over with sufficient frequency. By speeding up the entire process of manufacture, and carrying less inactive finished stocks, it is found that more business can be done with less capital, thus increasing the percentage of profits on the business done by a more rapid turnover in capital. Such a change followed a decision which was based upon accurate statistical information.

One company, building and selling a variety of types and sizes of machinery, found that it cost an average of $3.50 just to handle the paper work necessary to enter an order in the factory. Many small orders came in for simple repair parts valued at only a few cents, each one of which cost much more to handle than the value of the order itself. With this statistical information available, it was decided to establish a minimum billing price of $1.00 upon each order, which eliminated a share, at least, of the existing loss on small orders. Further examination of statistical data on various items of cost led to establishing lower prices upon a quantity of duplicate items when ordered and shipped at one time.

Thus, in every phase of activity within a business organization, statistical information is necessary if wise decisions are to be made. The problem before any organization, however, is to determine what statistical information is essential and what can be dispensed with in the interests of economy, for frequently the collecting and maintaining of elaborate statistical information has, in itself, become a costly and burdensome matter.

A detailed consideration of the accounting methods used in business enterprises constitutes a course in itself, and is far too broad to be included in this book. The importance of a knowledge of business statistics to the young engineer can scarcely be overestimated, however, and for that reason this chapter will show the information that a competent accounting system can furnish, and the limitations of such data. The really vital point is that the student engineer may gain a critical understanding of accounting, the need for it, and its possibilities and weaknesses as a basis for engineering analysis.

When business units were small and cash was demanded with each purchase, detailed records were unnecessary. Even today, many one-man establishments come under this classification. But, with the greatly increased size and complexity of modern business enterprises, numerical records have become an absolute necessity. And, although accounting records have developed to the point where they are indispensable, the business man now feels the need for even further data than the dollars and cents records in his books.

The growth of business has brought with it tremendous quantities of data and figures which are necessary to measure the output and efficiency of the business unit. With this increase in size of the industrial units, the data become so complex and all-embracing that the determination of the actual significance of all these figures becomes increasingly difficult. Many authorities believe that this very factor is largely responsible for the operation of the law of diminishing returns after the business unit reaches a certain size.

To enable the executives of business concerns to make the maximum use of cost records, sales records, market analyses, and so forth, a quantitative method not restricted to any single type of mensuration had to be evolved and adapted. It was found that the methods followed for many years in scholarly studies for the condensation and analysis of data would serve very well for engineering, business, and industry. This subject of statistical methods and the presentation of data is a broad one, but an attempt will be made to introduce the fundamentals to the engineer.

The statistical methods now used in business have not arisen from business itself. These methods have long been known and applied in economics, psychology, sociology, and the natural sciences. Of recent years, they have been taken from the academic realm and adapted to the peculiar needs of business. Statistical methods have become indispensable in the operation of large merchandising units, and in dealing with the data on traffic required by railroads and other traction companies; and they are the very foundation of life insurance companies. They underlie scientific management and the sampling theory that is so necessary to the quality control of technical products in manufacturing establishments. We shall learn more of quality control later in this chapter.

The data used in business statistics come from various sources. Many of them are taken directly from the accounting records of the individual business. Some of them often come from an outside agency such as the government, which collects the data and disseminates them in various publications.[1] In some cases, a trade association gathers data from all members, and then gives the assembled figures to each individual member. In many cases, the data must be collected by the investigator, through study schedules filled out by personal canvasses, or through mailed schedules. The data thus obtained are tabulated and arranged to tell their story in the most vivid form possible, many times being compiled in graphic and chart form. These data are then analyzed, and an attempt is made to draw from them unbiased and logical conclusions.

There is a growing tendency for such statistical work to be used in forecasting business conditions so that the entrepreneur may determine his policies sufficiently far in advance. John R. Riggleman and Ira N. Frisbee, in their book "Business Statistics," cite several of the many cases that have proved the practical value of statistical work in this connection. For example, the American Telephone and Telegraph Company bases its plans for the future on its statistical analyses. The Dennison Manufacturing Company refused to be swept along in the

student in search of statistical information will find it very helpful to consult the "Condensed List of Publications," issued by the United States Department of Commerce, Bureau of Foreign and Domestic Commerce, United States Government Printing Office, Washington, D. C. This pamphlet lists timely and recent publications of the Bureau of Foreign and Domestic Commerce, relating to statistical information of all kinds, gathered by the government.

All publications listed will be available for examination at any of the district or cooperative branch offices of the Bureau. District offices stock these publications for immediate delivery; most of the cooperative offices do not stock publications for sale but will take orders for them.

general expansion of 1920, and as a result came through the depression of 1921 at 96 per cent of normal. The American Radiator Company likewise lays plans according to its statistical analyses, and for the past thirty years has increased inventories and expanded during slumps, and liquidated at the high prices of prosperity peaks. Numerous other examples could be mentioned, but these suffice to show the growing acceptance of statistical analysis as a practical guide to business policies.

Methods of Accounting. We shall now make a brief review of methods of accounting. The most elementary type of accounting is known as the single-entry bookkeeping type. Although long antiquated in large establishments, it is still used in some small mercantile houses where the keeping of accounts with creditors and with customers is all that is necessary.

The modern system of bookkeeping is known as the double-entry method. It purports to answer the two most vital problems that concern every business executive, namely:

1. Whether the business concern has shown a profit or sustained a loss during a stated period of time, and how much?
2. At any given moment, what is the state of the business concern as regards liabilities and assets, and what is the book value [2] of the enterprise?

In simple terms, then, double-entry bookkeeping furnishes a "profit and loss statement" for a given period of time that serves to answer the first of the two vital questions above. Also, it affords a "balance sheet" to give a complete picture of the financial status of the company at any moment of time, which serves to answer the second question. Let us study, first, the simple balance sheet of the "X. Y. Z. Company" shown on page 168.

This balance sheet has been greatly simplified and presented in round numbers for the sake of clearness. It will be observed that the assets are valued at $150,000. The liabilities are $40,000, of which amount $35,000 are subject to payment in the near future, and therefore termed "current liabilities." Subtracting the liabilities from the assets gives us the net worth of the company or $110,000 ($150,000—$40,000).

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[2] "Book value" of a company is the total assets less total liabilities, including debts of all kinds. Dividing by the number of shares of stock held by stockholders, one obtains the "book value" per share of stock. Usually it differs from the market value of the share of stock, dependent upon earnings or losses or the future possibility of these.

X. Y. Z. COMPANY
BALANCE SHEET
As of December 31, 1937

ASSETS

Current Assets:		
Quick Assets:		
Cash	$20,000	
Accounts Receivable	5,000	$25,000
Working Assets:		
Inventory		75,000
Total Current Assets		100,000
Fixed Assets		40,000
Prepaid Expense		10,000
Total Assets		**$150,000**

LIABILITIES (AND CAPITAL)

Current Liabilities:		
Notes Payable—Bank	$ 8,000	
Notes Payable—Trade	4,000	
Dividends Payable	7,000	
Accounts Payable	15,500	
Accruals Payable	500	
Total Current Liabilities		$35,000
Long-Time Liabilities		5,000
Total Liabilities		40,000
Net Worth as represented by:		
Surplus	$40,000	
Capital Stock	70,000	
Total Net Worth		110,000
		$150,000

The dual nature of the double-entry system is seen here. Since each transaction has a double effect on the balance sheet, the equality of the sheet remains unaffected. Thus, for the manufacturing company above, if the inventory of raw materials is increased by purchasing on credit, the assets are increased but the liabilities must be increased by a like amount. If some of the finished goods are sold at a profit, the assets (cash or accounts receivable) are increased by a larger amount than the asset of inventory of finished goods is decreased, the difference representing the increase of net value or net worth of the enterprise. This is readily seen from the balance sheet.

The balance sheet of the X. Y. Z. Company was purposely made simple in order to bring out the various points of importance that were in question. It must not be thought, however, that all companies have

so simple a balance sheet, but on the other hand, no matter how complex the sheet is, this same information and none other is included. To show the complexity of the typical balance sheet, the forty-first annual report of the Union Pacific Railroad for the year ending December 31, 1937, is reproduced in part, the balance sheet being shown at the end of this chapter. This sheet was selected because of its complexity and yet its clearness. The assets are seen to be $1,206,243,128.02 while liabilities are $849,320,725.87, of which $21,697,990.79 are "current." It is thus seen that, even though this actual balance sheet is complete to the most minute detail necessary to a stockholders' report, it is still relatively simple to interpret.

If the accounting system were to list each individual transaction in a large business, so that the balance sheet would show immediately the change in net worth with each transaction, the ensuing complexity would soon destroy the value of the records. To obviate this, the accounts are split up into many smaller subdivisions, each of which covers numerous transactions. These are all "closed out" at the conclusion of each fiscal year, and a consolidated *profit and loss statement* set up. This statement is of great value in increasing the information that may be obtained from accounting records. On page 170 is the simple profit and loss statement of the previously mentioned X. Y. Z. Company whose balance sheet was considered. Again, like the balance sheet, this statement is simplified in order to bring out the main points.

The profit and loss statement reproduced here is self-explanatory and furnishes an insight into how these statements are compiled and of what value they are to a business enterprise.

Business Ratios and Comparisons of Statements. In analyzing financial statements, it is common to consider what we call "business ratios" as interpreting the financial status of the company. The meanings of a few of the more popular ratios are explained below.

The *current ratio* is obtained by dividing the current assets by current liabilities. Such a figure shows the condition of the company in relation to its ability to satisfy current obligations from liquid assets. Referring to the balance sheet of the X. Y. Z. Company on page 168, $100,000 divided by $35,000 shows a current ratio of 2.86 or 286 per cent. Ordinarily, well-managed companies maintain a current ratio of 2 or higher. The importance of the current ratio in evaluating the financial position of a concern applies particularly in comparing the position of companies in the same line of business and for the same date. Current ratios will vary with seasonal fluctuations and with business conditions.

X. Y. Z. COMPANY

Profit and Loss Statement

Year ended December 31, 1937

Gross Sales	$138,000
Less: Returned Goods	3.000
Net Sales	
Cost of Goods Sold:	
Inventory at beginning of year	70,000
Purchases	100,000
Freight	5,000
	175,000
Less: Inventory at end of year	75,000
Cost of Goods Sold	100,000
Gross Profit	35,000
*Operating Expenses	20,000
Net Operating Profit	
Other Income	-
	15,500
Other Expenses:	
Interest	900
Taxes	600
	1,500
NET PROFIT	**$14,000**

* In the usual profit and loss sheet, this item of Operating Expenses would be subdivided into all its main groupings such as salaries, rents, taxes (city and state), power, fuel, depreciation, office expenses, traveling expenses, advertising, donations, and all the other items that go into operating expenses. These were not shown for the sake of clarity for the statement.

A glance at the Union Pacific statement at the end of this chapter shows that, for the year of 1937, this company's current ratio was approximately 234 per cent.

The ratio of *sales* to *fixed assets* is of value in that it shows, among other things, whether or not in an expanding business the additional equipment is productive of sales, and hence warranted.

The ratio of *net worth* to *fixed assets* is significant for making comparisons from year to year. When this ratio is high, the *liquidating* protection to creditors is greater than when the ratio is low.

The ratio of *net worth* to *total debt* is indicative of the proportion of owned to borrowed capital. No single ratio may be set up as a criterion, since a ratio that is considered conservative for one industry may be cause for alarm in another.

It will be observed from the terms employed in expressing these

ratios how they fit in with the balance sheet and profit and loss sheet. From these two statements, any of these ratios may be easily calculated, and, for comparison purposes, one needs only the reports of the companies he wishes to compare.

The *100 per cent statement* is another useful device for comparing the financial condition of one company with that of another, or for studying the condition of an enterprise over a period of years, in which case the significant factor brought out is not the change in an asset from year to year, but its change in relation to the total. The following is a simple illustration of the 100 per cent statement from "Business Statistics," by J. R. Riggleman and I. N. Frisbee (McGraw-Hill Book Co., Inc., New York, 1938), p. 578.

EXAMPLE OF A 100% STATEMENT

	Company A		Company B	
ASSETS	Amount	%	Amount	%
Cash	$4,000	4.0	$12,000	2.4
Receivables	15,000	15.0	50,000	10.0
Merchandise	10,000	10.0	40,000	8.0
Total Current	29,000	29.0	102,000	20.4
Fixed Assets	69,000	69.0	383,000	76.6
Deferred Charges	2,000	2.0	15,000	3.0
Total Assets	$100,000	100.0	$500,000	100.0
LIABILITIES AND NET WORTH				
Notes Payable	$6,000	6.0	$10,000	2.0
Accounts Payable	8,000	8.0	20,000	4.0
Other Current	3,000	3.0	2,000	.4
Total Current	17,000	17.0	32,000	6.4
Bonds, etc.	20,000	20.0	150,000	30.0
Total Liabilities	37,000	37.0	182,000	36.4
Net Worth	63,000	63.0	318,000	63.6
Total Liabilities and Net Worth	$100,000	100.0	$500,000	100.0

EUGENE CALDWELL, "When Your Banker Begins to Ask Questions," *American Business*, August, 1938, p. 9.

ROY A. FOULKE, "Financial Ratios Become of Age," *Journal of Accounting*, September, 1937, p. 203.

COST ACCOUNTING

It has been seen that the accounting methods used in developing financial statements are largely retrospective. By means of such methods, we can tell what was done in the past week, month, or year—all of

which is a matter of history. But such records are almost useless when it comes to discovering our mistakes and inefficiencies in sufficient time to do something about them. We must have a means of securing information on our operations, broken down in such a manner that we may thoroughly analyze each phase of the business; yet such information must become available promptly if steps toward correction of inefficiencies are to be taken.

To facilitate planning in the future, there has been developed a system of "costing accounting" and "standard costs,"[3] by which we can compare our operations to an adopted standard. Standard costs are arrived at by breaking down an operation into its various parts, the costs of which are based upon past experience. They provide a means of getting directly at the particular phase of the work that is falling behind its standard and causing a variation in the costs. With costs so broken down, a complete analysis is easily and quickly made, when costs take an unusual change, and the root of the trouble can be determined and corrected. The principal purpose, therefore, in cost accounting, is that of cost control,[4] for it enables management to determine where losses occur and take steps toward improving efficiency by their elimination.

It should not be inferred, by what has been said, that cost accounting is applicable only in factory operations. Inefficient distribution, or inefficiency in any other important branch of company activity, may contribute to the downfall of a company just as much as inefficiencies in manufacture. For this reason, cost accounting has taken its place in selling[5] and administration, as well as manufacture. Cost account-

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[3] Reference: "Objectives of Standard Costs and Their Use in Measuring Performance," Earl A. Green, *Production Papers, Seventh International Management Congress* (American Management Association, 330 West 42nd Street, New York City), p. 173.

[4] According to Percy F. Brown in "The Industrial Engineer's Part in Developing Cost Control Methods" (special publication of Society of Industrial Engineers, 205 W. Wacker Drive, Chicago, May, 1933), there are two major control tools of operating management. They are control of production through: (1) scientific routing, scheduling, and dispatching, and (2) cost figures. The former deals with flow of product through manufacturing processes; the latter, with costs of this flow. Cost figures should be simple, easily interpreted, and concise for control purposes. Their value for control decreases rapidly if management is kept waiting for long for cost figures, and for this reason daily postings of cost figures are necessary if they are to be timely for purposes of control.

[5] A large manufacturing company, selling industrial equipment, supplies many of its salesmen with automobiles for business purposes. For some years, an te record was kept of the cost of operating these automobiles, including of upkeep, operation, depreciation, and interest charges. It was particu- rable to establish a point at which it would be most economical to tomobiles with new ones. From reliable and accurate records, it

ing provides the production end of the business with timely pointers to inefficient practices which can be eliminated.[6] To the sales department, cost accounting enables wiser product pricing,[7] and through standard costs proper prices on special products or infrequently manufactured items can be quoted intelligently.

Cost accounting assists also in the work of forecasting performance upon the basis of engineering principles. By means of it, costs are predetermined and set up as goals for every part of the business. Certainly, then, cost accounting is an important element in *control* of a technical organization.

The cost accountant supplies a ready comparison of actual costs with forecasted costs of every operation. Such comparisons bring out the reason for and origination of any variation in costs as a whole. By having an efficient and cooperative system of cost accounting, it is no longer necessary to rely entirely upon inspection, time study, and rigid observation of operations to locate a trend away from efficient operation.

In the older forms of accounting, a manufacturer took an inventory accounting of finished products, goods in process, raw materials and other assets, at the end of each fiscal year[8] or selected period. Such inventories furnished a reasonably accurate picture of values at that particular time, for use in determining a statement of assets, and also a profit and loss statement covering the period. Being made infrequently, it did not make possible prompt correction toward elimination of losses that developed from such analyses, and consequently allowed a considerable lag in the use of the statement for purposes of cost con-

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was found that, on the average, it would pay best to replace the automobiles after 25,000 miles of travel, which usually represented one year's service.

[6] A manufacturer, using large quantities of silicon sheet steel for punchings included in the manufacture of electrical apparatus, determined from his cost accounting system that a considerable loss occurred in value of materials wasted as excess in the punching operation. A close examination of these losses led to the purchase of sheet steel of entirely different dimensions, and also a scheme for utilizing waste sections for still smaller punched sections which were required for small-sized types of electrical apparatus.

[7] In trade associations, made up of manufacturers forming a part of a particular industry, progress toward price stabilization has been made by establishing uniform methods of cost accounting. When any manufacturer knows his actual costs, he is much less likely to quote unreasonably low or high prices.

[8] The "fiscal year" means the *business year* which has been adopted arbitrarily by each company as a matter of policy, and which may or may not correspond to the calendar year. For instance, to avoid the confusion incident to the annual holiday season at the close of each calendar year, a company may select the "fiscal year" ending March 31, or September 30. The United States government fiscal year starts July 1.

trol. Such weaknesses have encouraged the inauguration of cost systems applying to all operations, which develop reliable cost figures in the shape of a running record.

Although cost accounting applies to all phases of a company's operations, we will summarize its purpose in relation to production of technical products as follows:

> To determine values for purposes of arriving at a financial statement of assets and operations over a given period of time.
>
> To determine the cost of current operations, in order to eliminate losses and improve efficiency.
>
> To determine the volume and value of materials and products, for purposes of their control.
>
> To determine the cost of a particular operation, product, or line of products, in order that reliable information may be obtained upon which to base prices. For instance, a manufacturer must know what a particular product costs, or a contracting engineer must know what his costs are in designing and erecting a structure, if production is to be profitable.

Aspects of Cost Accounting. In production processes, it is not difficult to determine the cost of labor required, or the amount and value of materials used. These items can be established for a given job, item produced, or quantity. The numerous indirect expenses, such as cost of administration, supervision, indirect labor, light, power, and depreciation, can, without great difficulty, be determined for a specific operating company, but when we attempt to allocate a proper division of these expenses to a given product, the problem becomes complicated. Any cost accounting system, to be of value, must obviously provide this, and a *proper share* of these "indirect" or "overhead" expenses must be allocated to the individual item of production. Such allocation must also be made on the basis of averages, for any method of allocation which is truly exact would require such an amount of work as to become overwhelming and costly. For instance, it would be impossible for the manufacturer of a quantity of small compressors for commercial refrigeration systems to charge against each one of these its exact indirect expenses. Individual compressors may require special work in adjustment, some may remain in the warehouse months before being sold, and certainly the sales expense upon each one will differ. Furthermore, the rate of manufacture over a period of time may vary greatly, and idle manufacturing equipment is costly. In the application of these indirect expenses, the cost accountant applies the law of averages.

Consider the salvage value of a machine tool. The accounting

system of a plant sets a certain depreciation rate on the machine, estimates its life at so many years, and sets the salvage value at first cost minus total depreciation. Obviously, this is just an estimate, and unforeseen conditions may cause a material difference in the actual scrap value and book scrap value. If it were necessary for the accounting to be strictly accurate, the books would have to be corrected, possibly as far back as fifty years, to compensate for the error made in the depreciation estimate. This is, of course, impractical and hence throws the costs off to some degree.

Eugene L. Grant, in his book "Principles of Engineering Economy," cites a very good illustration of this point. He tells of a certain industrial engineer who made a study of a power plant with an eye to reducing operating costs. During his studies, the engineer found that the stored coal was much less than the inventory shown in the books. Some months later, this engineer was unpleasantly surprised to find that the cost accounts showed the operating cost to have gone up rather than down. At first thought, the inference was that his study had been a complete failure. But investigation proved that the accountant was spreading the cost of the fuel shortage over the next six months, rather than charging it off to the month in which the shortage had been discovered. This avoided distorting the costs for that particular month, but completely overbalanced the economies that had resulted from the engineer's studies, and hence gave the false impression that so startled the engineer at first.

Along this same line, it would obviously be unfair to charge off a "sunk cost" to a new machine. For example, suppose that the accounting department erred in depreciating a certain machine tool, and hence must in some manner charge off \$1000. If this were charged to the new machine, it would probably make the replacement appear unprofitable. The new machine tool would be getting off with a bad start—\$1000 already against it, and under such circumstances, the cost study would be unfair to the new machine. The engineer must be alert to catch such errors when using cost data for economy studies.

Another cost accounting practice that may give a distorted picture is the allocation of expenses on productive machinery. The allocation to each machine of such expenses as indirect labor, lighting, heating, and other items of factory overhead is often apportioned approximately, and on a percentage basis. As a result of this practice, a process performed on a certain machine, if we consider this assigned portion of overhead which this machine must bear, may appear much more costly than it actually is, so that the decision to replace equipment should certainly not be made on this basis alone.

The manner in which expenditures are allocated to various accounts also will always bear the closest scrutiny on the part of the engineer. Often the accountant oversimplifies the allocation to a particular account, since he feels secure in the knowledge that, in the final compilation of accounts, all expenses will ultimately be included. But what if the engineer should take one particular account that has been oversimplified, and use it as a basis for an economic study? If he does this uncritically, his conclusions may be incorrect.[9]

These are but a few of the limitations to be found in the average cost system. The engineer who knows how the costs have been obtained will be cognizant of these limitations, however, and will not be inclined to accept cost data unquestionably. Cost accounting is a valuable tool, but it is not set up primarily for engineering use, and hence must be applied cautiously if it is to be successful.

The Cost Department. Although there is little or no dispute as to what a cost accounting system should do, there is much debate as to how it should be set up to accomplish these functions, and what system should be used in accomplishing it.

Those assigned to the responsibility of cost accounting have the duty of identifying all forms of cost and determining their amounts, and arranging, combining, and establishing these costs in a form which can easily be used. Since a producing enterprise deals with the number and nature of items produced, and the dollars received for them in their completed form, costs must be made available in these specific terms.

The customary method of cost accounting involves determining the labor and materials content involved in producing a given product, and then adding thereto, on a ratio basis, the various items of cost which include all forms of indirect expense. Thus, if we consider a given item produced, we know the cost contents for labor and material, and finally add to these the cost contents for all classes of indirect expenses. In doing so, however, it is customary first to establish the shop cost, which includes all cost items applying to production, in- those items of an indirect expense nature which apply only

[9] A case in point is a cost study made by an engineer to determine whether a certain small college should purchase its power from a local utility or continue to generate its own. Taking the accounts at their face value, the college power plant was, by far, the cheaper source of energy. But, on scrutinizing the accounts more closely, the engineer found that the wages of several firemen were not included as an expense of operating the power house, since part of their time was taken up as grounds keepers and the like. This, and several other oversimplified llocations of expense, put an entirely false light on the picture. The college is the power from the utility, and saving money, at th

to the manufacturing department or shop itself. With the shop cost established, to this is then added those indirect expenses which have nothing directly to do with manufacture, such as the cost of administering the company, research and design, sales, and collection expense.

In allocating general overhead costs, several arbitrary systems have been set up, the more important of which are as follows:

1. Those based on a percentage of direct labor costs.
2. Those based on a percentage of the cost of materials.
3. Those based on a percentage of the total shop cost.
4. The machine-hour system.
5. The man-hour system.

Each of these methods has its advantages and disadvantages, and for an impartial survey, the reader is referred to the many good works which have been written on this subject.

Many industrial concerns set up what is termed a "standard" cost, previously mentioned. The standard cost is usually found in plants where products are standardized and duplicated in manufacture. It represents the normal cost of a product, and gives a figure with which actual costs can be compared, thus providing a check on the operating conditions. The standard cost is not completely static, but must be revised with broad changes in operating factors.

This very brief survey of cost accounting would not be complete without a word on the subject of uniform methods of cost accounting, applying to various manufacturers of the same class of product. This has become prevalent in most industries, and the United States Government has encouraged it as sound practice. Uniform methods of cost accounting have been worked out for the electrical manufacturers, printing and paper industry, and many others. By using this uniform system, the smaller manufacturers are able to determine their costs without prohibitive expense; thus the entire industry is spared the disturbing influence of a high mortality rate such as is often caused by the inexperienced manufacturer, who unwittingly sells below his costs and is eventually forced into bankruptcy.

INDEX NUMBERS

Throughout this book, charts and graphs appear showing the variations of price, quantity, and other magnitudes over a period of time, or at different places. These invariably are constructed on a basis of index numbers for the sake of simple comparison. Index numbers are more than the ratio of a variable, at any given value, to some

one value which has been selected as a base. The base of any index number system usually will be one of the set of numbers being compared (usually the one considered most representative of normal[10] activity), or, sometimes, an average of all the values. In short, the index number is but a common denominator to which we may reduce prices, production, wages, purchases, or what not, when they are to be compared over a period of time or at various places. Only by index numbers can a series of values be made truly relative to one another.

The most commonly used index numbers are the *single series relatives, aggregate index numbers,* and *relative-from-aggregate index numbers.*

Construction of *single series relative index numbers* is merely a matter of finding the ratio of the data at a given point to those at the base point. For instance, consider a pump manufacturer whose sales volume on one line of pumps was as follows:

1926—2500	units	sold
1927—2730	"	"
1928—2410	"	"
1929—2260	"	"

We can say that 230 more units were sold in 1927 than in 1926, 90 less in 1928, and so on, but unless we know the volume in 1926, we are unable to tell whether the increases and decreases are great or relatively insignificant. However, if we take 1926 as a typical, normal year and express sales of other years as a percentage of those in 1926, we have a ready comparison that tells us whether the changes are large or small. Letting 1926 sales be 100 per cent, the sales for 1927 are $2730/2500 \times 100 = 109.2$ or 9.2 per cent higher than 1926. The single series relative index number for 1927 is 109.2, and we can see at a glance the significance of the number. In 1928, it is 96.4, or 3.6 per cent less than 1926; 1929 is 90.4; and so on. The simple formula for converting data into single series relative index numbers is:

$$N_1 = \frac{Q_1}{Q_b} \times 100$$

Where N_1 is the index number of the particular period, Q_1 is the figures or data of the particular period, and Q_b is the data during the base period. Most of our charts in this book are constructed from just such a simple formula.

[10] The base of a chronological index is that period from which we are going to measure variations in other periods. In selecting such a base, a period should be selected which is as nearly normal as possible.

Aggregate index numbers are numbers growing out of the combination of several series. Assume that the pump manufacturer sells five lines of pumps. He wishes to construct an index showing sales for the year 1938 compared to those in 1926, taking all lines of product into consideration, instead of just one. His data on the five lines are as follows:

	1926			1938		
	Units	Price	Total Sales	Units	Price	Total Sales
Pump A.	2500	$100	$250,000	2050	$110	$225,500
Pump B.	1250	125	187,500	1020	140	142,800
Pump C.	750	140	105,000	660	150	99,000
Pump D.	1420	165	234,300	1650	175	288,750
Pump E.	880	210	184,800	710	240	170,400
Total.	6800		961,600	6090		926,450
Relative index number.	100		100	89.6		96.3

The manufacturer can prepare a simple aggregate index number by adding the total number of units sold in the five lines for 1926 and 1938. Hence, in the table above, a total of 6800 units was sold in 1926 compared to only 6090 in 1938. These are aggregate index numbers. Then, with 1926 as 100, the *relative-from-aggregate* index number for 1938 is 6090/6800 $\times$ 100 or 89.6, which shows sales to be 10.4 per cent under 1926. The simple relative-from-aggregate index number formula becomes:

$$M_1 = \frac{\text{Summation of } Q_1}{\text{Summation of } Q_b} \times 100$$

We should note the fact that, in the illustration above, we have comparable units in all five lines and hence can use direct aggregates. Where the units of various series are not comparable, we must compute relatives for each series and then take a summation of the relatives.

This brings us to the point of questioning the results of the simple aggregate index numbers shown above, as a true index of sales volume. In the first place, this index gives equal emphasis to each of the five lines, disregarding the fact that there is considerable price differential between the lines. An index of sales volume should show the true trend of sales, and to do that we must have a measure of total income from sales on all lines. Too, prices have changed since 1926, and this

tends to make the sales volume appear incorrect if we consider units only.

We can correct much of this by a process known as "weighting" the index number, in which we introduce "weights" which will serve to place proper emphasis on each line. In our example, price variations will be used as well as units sold, and hence we will get a truer picture of sales volume. We weight our index numbers by multiplying the quantity of each line sold by the prevailing price, as shown in column 3 of the data table. Then the summation of total sales for each line is carried out as before and we find that, for 1926, the aggregate index number is $961,600 as compared with $926,450 in 1937. Going on and constructing the relative-from-aggregate weighted index number, we get 926,450/961,600 × 100 or 96.3 for 1937, which is only 3.7 per cent less than 1926. We see, then, that the weighted index numbers are much more reliable since they place emphasis where it should be placed and in proper proportion. The formula for the weighted relative-from-aggregate index number in this case is:

$$N_1 = \frac{\text{Summation } (Q_1 \times P_1)}{\text{Summation } (Q_b \times P_b)} \times 100$$

where P_1 and P_b are the prices during the present period and the base period of 1926, respectively. The example of weighted index numbers should be considered only as such, since the variations in weights are many. More often, quantities are used as weights where price indexes are desired. The choice of weights is an important one to the construction of true index numbers.

Index numbers have become increasingly popular for expression of statistical data of all kinds, and it is important to know the principles of their construction before trying to interpret them. Index numbers are generally used in graphical presentation of data. They are especially valuable in showing such items as sales volume compared to value of sales, plant conditions, general business conditions, efficiencies (especially where many operating ratios are involved), and a multitude of other facts.

Just one other point should be mentioned regarding manipulation of index numbers, and that is comparison of index numbers which have come from different bases. Suppose that we wish to compare an index using the base year 1926 with a system based on 1913. We must reduce both index number systems to a common base if comparison is to be accurate. To do this, we need only select the common base year and divide each index number (as computed on the old base) by the

index number appearing at the base year, and reduce the result to a percentage. For example, we have relative index numbers based on 1913 as follows:

1913....................	100
1920....................	152
1926....................	120
1930....................	105

We wish to change these numbers from the 1913 base to a 1926 base for sake of comparison with other index systems based on 1926. The new numbers are calculated as follows, and will have their new base as 1926:

1913....................	$100/120 \times 100 = 83.3$
1920....................	$152/120 \times 100 = 126.6$
1926....................	$120/120 \times 100 = 100.0$
1930....................	$105/120 \times 100 = 87.5$

REFERENCE

"The Index of Business Activity—and How to Use It," *Business Week*, September 17, 1938, p. 35. An explanation of how *Business Week* prepares its index of business activity.

ENGINEERING STATISTICS

We are now entering into the discussion of a subject that borders more on the theoretical than does the subject of business statistics that we have just been considering. Under "Engineering Statistics" we are going to investigate methods for the presentation of data; methods that were once thought of only in connection with studies such as those in the social sciences and biology. But these very methods have been taken from their academic realm, and are now universally applied to such matters as industrial sampling and the quality of technical products, which are discussed later on.

Data Gathering and Tabulation. At the very beginning of any statistical survey, we have our data. These may relate to the number of people passing a certain corner each day, the number of automobiles that cross a certain bridge each hour, the tensile strength of heat-treated steel bars, or the octane ratings of different brands of gasoline.

First, we must ascertain how these data were collected. We should know the test conditions under which the data were taken. Were the conditions uniform throughout the period or periods of observation? Did unavoidable human factors enter in? Were the testing machine

and the observer accurate? These and many other questions will bear close investigation.

The data may need simplification and classification before any warranted conclusions may be drawn from them. Before data on the earnings of factory workers can be compared, they may need grouping by type of work, time of work, piece work, salary, sex of the workers, and the like. Studies of the deaths per thousand of population are of most value only when grouped according to age periods, occupational classes, racial groups, and so on. These sub-groups must then be treated as definite divisions for independent analysis. Merging these divisions will often result in a condensed presentation of but slight significance.

Once the data have thus been classified, simplified, method of compilation checked and approved, and the validity of their comparability ascertained, the next step is to arrange and condense the data into the form best adapted to their practical use. The arrangement of a mass of ungrouped data into an orderly sequence *according to magnitude* is called an array. Table 1, page 183, shows the original, unclassified data on 100 samples of steel tested for tensile strength or stress. Table 2, page 183, shows the array of these data in an order of ascending magnitude. Such an arrangement of data is known as a frequency distribution. Next, these data may be condensed and further classified into groups as shown by Table 3, page 183. Here, grouping is done by finding the number of samples that fall between definite tensile stress limiting values that go to make up each group. Hence, this table merely gives the frequency at which the test values were found in each of the chosen groups of values. This form of presentation is likewise a frequency distribution, and, although it involves a great loss of detail, the net result is a presentation that is much more readily understood.

In constructing a frequency table, a number of steps must be taken. These steps can be followed in Tables 1, 2, and 3, which represent the construction and condensation of data into frequency tables. First, it was seen, the items were arranged in order of magnitude as shown in Table 2. This step helps in visualization, but is not strictly

Next we determine the upper and lower limits by inspecting the data, decide on the number of classes to be used, and fill in the cases that fall in each class. These simple steps are all that is necessary, but certain decisions must be made in each step.

In the first place, a decision must be made on the size of the class

TABLE 1

UNCLASSIFIED DATA ON 100 TENSILE STRENGTH TESTS OF STEEL
Values given are pounds per square inch.

69,802	69,204	72,506	70,090	65,821	68,710	72,971
66,262	69,522	71,462	70,416	62,041	68,891	71,870
64,302	65,302	69,882	66,999	71,922	72,102	68,997
66,016	73,940	67,491	64,456	70,901	65,992	71,202
67,204	69,115	71,977	77,020	68,909	66,832	63,381
66,499	71,798	70,603	70,222	66,994	69,082	65,706
71,601	69,952	69,901	67,299	75,682	64,411	62,912
63,792	66,509	66,098	69,352	74,392	70,822	66,391
65,421	65,782	74,987	64,114	69,677	69,331	68,002
64,922	72,321	72,777	73,582	68,444	71,342	73,802
66,881	67,907	69,406	67,342	73,792	68,790	68,156
73,161	71,298	70,190	67,091	68,110	70,982	70,741
68,192	68,241	68,302	68,841	66,149	67,602	67,794
71,162	69,111	68,098	66,920	70,298	67,770	70,352
68,602	67,890					

TABLE 2

THE DATA OF TABLE 1 ARRANGED IN AN ORDER OF ASCENDING MAGNITUDE KNOWN AS AN "ARRAY"

This is also termed a "frequency distribution."

62,041	66,016	67,342	68,444	69,406	70,741	72,102
62,912	66,098	67,491	68,602	69,522	70,822	72,321
63,381	66,149	67,602	68,710	69,677	70,901	72,506
63,792	66,262	67,770	68,790	69,802	70,982	72,777
64,114	66,391	67,794	68,841	69,882	71,162	72,971
64,302	66,499	67,890	68,891	69,901	71,202	73,161
64,411	66,509	67,907	68,909	69,952	71,298	73,582
64,456	66,832	68,002	68,997	70,090	71,342	73,792
64,922	66,881	68,098	69,082	70,190	71,462	73,802
65,302	66,920	68,110	69,111	70,222	71,601	73,940
65,421	66,994	68,165	69,115	70,298	71,798	74,392
65,706	66,999	68,192	69,204	70,352	71,870	74,987
65,782	67,091	68,241	69,331	70,416	71,922	75,682
65,821	67,204	68,302	69,352	70,603	71,977	77,020
65,992	67,299					

TABLE 3

THE DATA OF TABLES 1 AND 2 CONDENSED AND CLASSIFIED INTO GROUPS

This presentation of data loses some of its former detail as shown in Tables 1 or 2, but it shows much more clearly the frequency at which test values fall into each grouping of values:

LIMITS OF GROUP	FREQUENCY OF OCCURRING
60,000 to 61,999 psi	0
62,000 to 63,999 psi	4
64,000 to 65,999 psi	11
66,000 to 67,999 psi	22
68,000 to 69,999 psi	28
70,000 to 71,999 psi	21
72,000 to 73,999 psi	10
74,000 to 75,999 psi	3
76,000 to 77,999 psi	1
78,000 to 79,999 psi	0

interval. The intervals should be so arranged that an even distribution will be made of the cases within each class. This is essential because later steps involve the use of the mid-value of each class as the representative value for the class itself. This, of course, involves error in the cases which are above or below the median, and a sufficient number of cases should be taken to keep this error small, without at the same time setting up too large a number of classes for easy comprehension. A general rule of having not less than 10 nor more than 25 classes is often applicable.

The decision of locating the class limit is of importance in that it can be made to simplify subsequent calculations. The tabulation of data is also made easier if the class interval can be made a whole number, the class limits integers, and if possible the medians also integers. The advantage of this is that it makes absolutely certain into what class an observed case falls and also establishes the median of the class in most simple form.

Class intervals should be uniform so that all groups or classes will be comparable. Similarly, all classes should be determinate. If an undeterminate class exists, it brings uncertainty into one or both of the limits, and greatly reduces the value of the table.

The tables we may prepare by the methods just outlined tend to reveal the underlying structure of our data as well as their basic unity. But this is just the beginning. We must employ other means if we are to show more concisely our data's true characteristics. The laws we shall use to condense our data to a few significant figures are universal and apply to practically any type of data.

Laws Governing Condensation of Data. The first concept we will consider is the "arithmetic mean." This constitutes or embodies the central tendency of our data. The arithmetic mean is simply the average of all the cases in our data, or of each subgrouping of data. It is a calculated average that represents the "center of gravity" of the distribution, and is affected by each value of the distribution. The formula for the arithmetic mean is:

$$M = \frac{\Sigma X}{n}$$

where M = the arithmetic mean.
Σ = the symbol for summation.
X = each individual case or observation.
n = the number of cases or observations.

Another useful concept is the "median." It is the value which is so selected that one-half of the number of cases lie above and one-half

below it. It is frequently used to establish the average of relative prices over a series of years, and where the average is not mathematically measurable. For instance, in the data below, the "median" is 63,167 pounds per square inch.

OBSERVED DATA ON 7 SAMPLES OF STEEL (TENSILE STRESS)

59,780 pounds per square inch	
61,456 " " " "	
61,987	
63,167	Median value
64,455	
65,111	
66,995	

A third type of "average" is the "mode." This is simply the value which recurs the greatest number of times, or the value about which the most cases occur. When we study frequency curves as representation of frequency distribution, we will recognize this "mode" as the maximum ordinate of a given frequency curve. It is of value when an average is needed that will not be affected by a few extreme cases. If, for instance, it were desired to find the average cost of a certain group of technical products, a few of which cost several hundred per cent more than the others, the modal average would be of value in that it would not be affected by the few extreme cases. But both the mode and the median are of little value when the number of cases is few, since they depend upon "position" for their usefulness. A large number of cases is required if a reliable position is to be established for the mode or median.

Let us suppose that our data are made up of the following numbers:

5 15,005 75 and 1000

Obviously, the average of these numbers would not tell us much. The one thing that is lacking in such a situation is some measure of the variation of skewness of the individual cases from the average.

The generally accepted means of expressing variation is known as the "standard deviation." The conventional symbol for this mathematical concept is the Greek letter sigma (σ). It is also known as the R.M.S. (root-mean-square) deviation, since it is obtained by squaring and totaling the deviations of each individual case from the arithmetical mean, obtaining the mean of these squared deviations, and extracting the square root of this mean; the significance of the title of root-mean-square deviation is thus seen.

Expressed as an equation, σ, the standard deviation becomes:

$$\sigma = \sqrt{\frac{\Sigma D^2}{n}}$$

where D = the individual deviations from arithmetic mean.
n = the number of deviations or cases.

Standard deviation may also be expressed as:

$$\ldots - M)^2$$

where $X_1, X_2, \ldots X_n$ = each case or item observed.
M = the arithmetic mean, as before.
n = the number of cases observed.

An equation that is still more convenient for computations, since it can be used readily with tables of squares and square roots, is:

$$\sigma = \sqrt{\frac{(X_1^2 + X_2^2 + \cdots X_n^2)}{n} - M^2}$$

where the symbols represent the same quantities as above.

The statement of the standard deviation tells the trained observer to what extent the individual cases vary from the arithmetic mean. It is the most important concept, at least from an engineering point of view, but there are others that cannot possibly be treated within the limited scope of this book.

Graphical Presentation of Data. Having seen how the statistician presents data in a mathematical form, let us turn to another method so much in use today, the graphical representation of frequency distributions.

Such diagrams as shown in Fig. 1 are referred to as histograms. In these, short horizontal lines are drawn to show the upper and lower limits of each class interval. It will be noted that the areas of the various rectangles are in direct proportion to the number of cases represented.

In using such large class intervals as in Fig. 1, the true facts are distorted. A truer conception is obtained by using smaller class intervals, as illustrated in Fig. 2. Then, by carrying this histogram but one more step, we obtain the completely smooth curve as shown in Fig. 3. This curve will permit accurate interpolation of points not in the original data. This curve is obtained by drawing through the points of the histogram in such a fashion that the area cut off from each rectangle equals the area added to the rectangle by the curve.

Strength of Steel in Tension

Histograms from data in Table 2, Page 183.

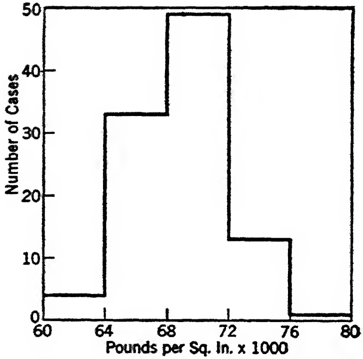


Figure 1. Class interval of 4000 pounds per sq. in.

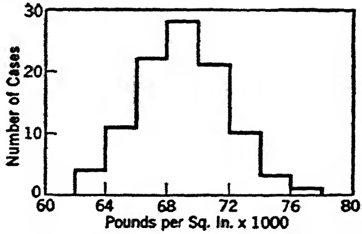


Figure 2. Class interval of 2000 pounds per sq. in.

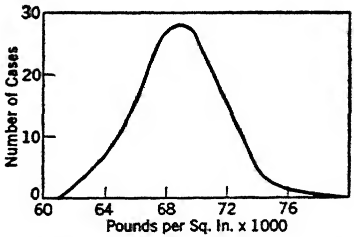


Figure 3. The derived smooth curve from the histogram of Figure 2.

In this manner, the smooth curve includes an area approximately the same as that of the histogram, which is obviously a necessity if the curve is to present the facts in their true light.

Another type of curve, known as the *ogive*, represents cumulative data. A curve of this kind is shown in Fig. 4, which represents the length of life of railroad ties, cumulative upward, while Fig. 5 shows the same data cumulative downward.

The ogive is well adapted to interpolation, and is unhampered by some of the restrictions applicable to the frequency curves in this respect. The ogive is in reality a graphical representation of the array, and can be drawn up from the array without the necessity of setting up a frequency table. It is very simply and easily prepared, and at the same time is an effective means of presenting quantitative data.

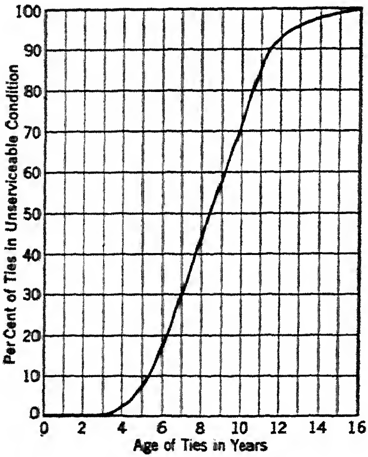


FIGURE 4. Ogive showing the life of railroad ties—cumulative upward.

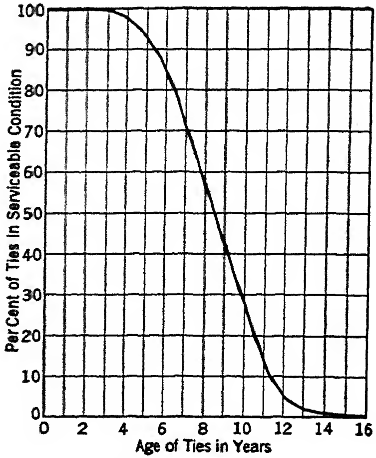


FIGURE 5. Ogive showing the life of railroad ties—cumulative downward.

QUALITY CONTROL AND SAMPLING BY STATISTICAL METHODS

All successful manufacturers of technical products have learned the economic importance of quality control. The scientific control of quality as well as uniformity involves first the determination of what "quality" is desired, and then the discovery and eradication of all possible causes of variation.

Quality control has become an increasingly serious problem as industry has attained its present gigantic proportions. New techniques, utilizing the old statistical laws and principles, have been developed for sampling and testing manufactured products. The theory of probability is at the foundations of these new methods, which are particularly applicable to quantity or mass production.

Let us imagine that we are manufacturers of gears. We make a very excellent grade of gear noted for its combination of toughness and hardness. But, in order to maintain our reputation, we must maintain the quality of our gears. How are we to tell whether or not every gear leaving our plant is really 100 per cent perfect and that it contains no hidden flaws?

One possibility is to test each gear with the scleroscope. Undoubtedly we will do this, since the test is easily made and is inexpensive. But this is not enough. We want to know whether our heat treatment is up to par. We want to know whether the "case" on our case-hardened gears is deep enough, or too deep, or too shallow. And the only

way we can obtain this information is by testing each gear to its destruction. On the other hand, little would be gained if we tested 50 or even 25 per cent to destruction, for this would be entirely too costly.

Here, then, we turn to the principle of sampling. Suppose that we take 1 gear out of every 20 that are produced, and test it to destruction. Would this be sufficient to indicate our maintenance of a high-quality product? We must turn to statistics and statistical methods for the answer.

The tests of our sample gear will be of value only if the gear is truly representative of the entire group from which it was taken. The product must be homogeneous, or sampling is invalid. If the group's variation in quality is within certain limits, the product is said to be "controlled," and such variations as do occur are due to chance. In such a case, the laws of probability are applicable, and it is possible to predict the quality of the product from the test of the samples. Our job is therefore to determine whether there are any variations in our gears *not due to chance.*

Setting aside the example of gears, now let us give consideration to any product that must be tested from samples—either where destructive tests are necessary, or non-destructive tests of each piece are uneconomical—the first point we must establish is whether or not our sample is truly representative. A sample usually must be taken at random, and must indicate not only the quality but also quality variation in the group from whence it came. Frequently, the selections of representative samples must be left to the discretion of the person whose duty it is to do the work.

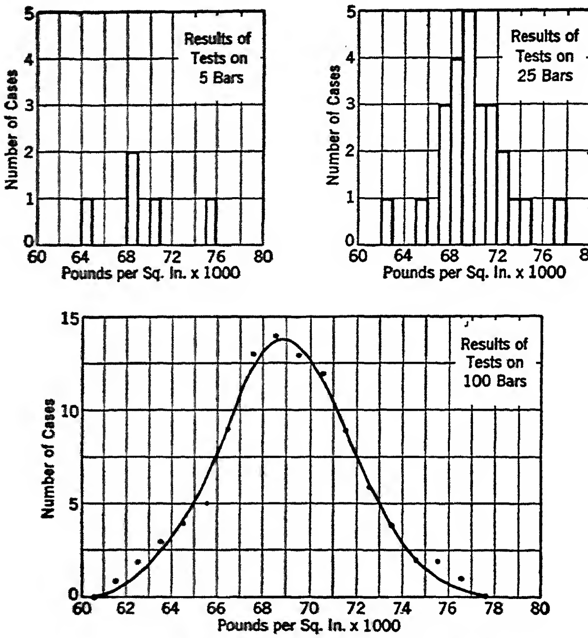
Each sample should be identified with a particular group or lot of material, or with certain manufacturing conditions, or anything else that may cause discrepancies between lots. Subgrouping with respect to time is frequently important in manufactured products, as well as grouping according to machines from which the product came, in order that variations may be traced to their source and corrected.[11]

If there is no known grouping that should be set up, the samples should be segregated into several groups, in the order in which the product was manufactured, 4 being a frequently used number of products constituting a sample. These samples should be as small in

[11] A good example of subgrouping is furnished by heat-treated steel bars. The bars could readily be grouped as to melts of the steel, and then subgrouped according to the various heat-treating charges. Assuming that there were 5 melts and 6 charges per melt, we should have 30 samples, since each of the 30 would possibly show some slightly different characteristics.

number as possible to prevent the average from covering up any changes that may have occurred during the manufacturing.

Let us now take any product, the quality of which we wish to control—the tensile strength of steel bars, for example. The value of the tensile strength will vary from one bar to another, owing to various causes. The "assignable" causes are those which we can identify as being responsible for the variations. Other causes cannot be determined for various reasons, and are termed "chance" causes. Appar-



: 6. Results of tests on 5, 25, and 100 samples of steel for tensile strength.

ently there is no absolute difference between chance and assignable causes. They are strictly relative, since a chance cause may become an assignable cause in the light of further knowledge.

In Fig. 6, we find the results of tests on steel bars in tension for 5, 25, and 100 bars. These curves are frequency distributions, so termed because they show the frequency with which the various test values for tensile strength occur. A test on 5 bars gives erratic results, but on 100 bars it gives a characteristic distribution, often referred to as the "bell-shaped curve." This curve shows the "normal" curve, or limiting form for frequency distributions. Since these bars were manufactured

under identical conditions, any variations in the test value are considered as due to chance.

Using the normal distribution curve and the standard deviation, it is possible to determine approximately what proportion of the total number of cases or test values will differ from the arithmetic mean, and by how much.

> Approximately two-thirds of the cases will lie between the range of average-plus-sigma and average-minus-sigma.
>
> Approximately 95 per cent will lie between average-plus-2 sigma and average-minus-2 sigma.
>
> Over 99.5 per cent will fall between average-plus-3 sigma and average-minus-3 sigma.

In those cases where the quality of the product is erratic because of lack of control of assignable causes, so that the variations are not due to chance, prognostication of the quality of the lot cannot be made by testing samples. By employing statistical methods, the manufacturer can determine whether a product is sufficiently well controlled to allow prediction of quality from tests on samples, and he will also obtain a measure of the degree of control of the product.

For a controlled product, statisticians have established the following limits for the arithmetic mean and the standard deviation of each sample:

Limits for the arithmetic mean:

$$M = \overline{M} \pm \frac{3 \cdot \bar{\sigma}}{c_1 \cdot n^{\frac{1}{2}}}$$

Limits for the standard deviation:

$$\sigma = \bar{\sigma} \pm \frac{3 \cdot \bar{\sigma}}{c_1 \cdot (2n)^{\frac{1}{2}}}$$

where $\overline{M}$ = average of the arithmetic means, M.
$\bar{\sigma}$ = average of the standard deviations, σ.
n = number of specimens in the sample.
c_1 = a factor dependent upon n.

If all the values of M and σ fall within these limits, the product is deemed controlled to an extent that justifies prediction of quality from tests on the samples. These limits are based upon the laws of probability and have proved their value in actual service.

In the use of statistical quality control by sampling, "control charts" are made upon which are shown the limits calculated for arithmetic mean and standard deviation. On these charts are then plotted the actual arithmetic means and deviations of each sample taken so

that, at a glance, one can tell both whether every sample is within limits or not, and also the degree of control of quality. Naturally, if the points representing each sample are near the arithmetic mean and standard deviation as calculated, rather than being located very near the limiting values, we know that the product is very well controlled. In the two figures shown here are plotted the arithmetic

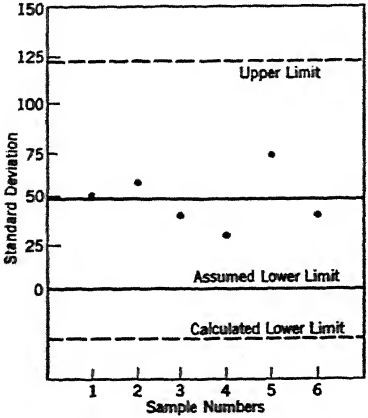


FIGURE 7. Control chart showing the limits calculated for standard deviation for a controlled product.

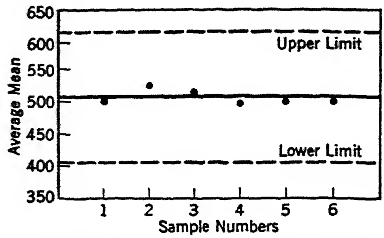


FIGURE 8. Control chart showing the limits calculated for arithmetic mean for a controlled product.

means and deviations of six samples of a product, taken from an actual case. We see that the product is very well controlled in quality, since all points in both charts are well within the confines of the limits.

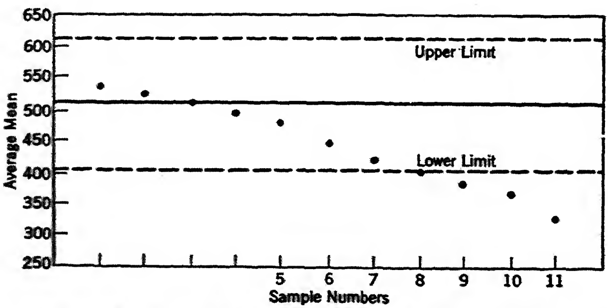


FIGURE 9. Control chart on which the trend of successive samples indicates that the quality of the product can no be predicted by sampling.

Now, for the sake of clearness, suppose that we have the same limitations as before for average mean, but that suddenly our samples begin to plot in a trend such as that shown in Fig. 9.

Here it is easy to see that the product is evidently being affected by some factor which is entering in to make the quality go out of control. If this factor cannot be located and the trouble corrected, sampling will no longer provide sufficient evidence to predict the quality of this product.

REFERENCES

W. A. SHEWHART, "Economic Control of Quality of Manufactured Product," D. Van Nostrand Company, Inc., 1931. An excellent treatment of quality control.

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BUDGETS

What is a Budget? In the discussion on principles and methods of planning, we found that intelligent economic procedure comes from a knowledge and evaluation of pertinent facts, and the development from these of a sound plan. We have also, previously, set down the principal elements of cost required in producing and furnishing economic products or services. Since every plan of procedure involves expense, such estimated expenses should be set down in advance, to guide and control operations. This we call a budget.[12] For instance, the budget applying to an enterprise for a given selected future period of time is nothing more nor less than an engineered financial spending program. Just as the engineer lays out a structure or a productive process to be followed, so, by budgeting, management lays out a program to be followed in the expenditure of funds.

The budget establishes, in monetary terms, an objective of performance, and, having been established with sufficient detail, it serves as a guide, as time elapses, against which to check actual performance, and in turn steer it properly.

The essential principles of budgetary control can be resolved into these three main steps:[13]

---

[12] "Budgetary control may be defined as accounting in terms of the future. It means a careful planning of all functions of a business in advance. These plans, which are contained in an instrument called for convenience "the budget," consist of a series of estimates of the business covering a definite period. As applied to mercantile and manufacturing enterprises the budget is a device for coordinating all the departments of a business. Estimates of the cost of operating every department are made for a definite period in advance and against these estimates cost of the actual performance is checked." (J. R. Hilgert in "Cost Accounting for Sales," The Ronald Press Co., New York, 1926, p. 32.)

[13] Reference: "Going to Make a Profit?" Samuel N. Selman, *Factory Management and Maintenance*, January, 1938, p. 92.

1. Forecasting performance, such as production or sales, and expenses of each activity, based upon carefully formulated plans for the budget period.

2. The coordination of these forecasts into a central unified plan that will be the controlling factor in a balanced program for the future.

3. At the expiration of each budgetary period, a "post mortem" to see where and why actual performance deviated from the forecasts. This is of value both to the management of the business, and in revising the forecast for the next period. This "yardstick" function of the budget, which may be carried on throughout the budgetary period by comparing actual with predicted performance, is of great value.

Why is a Budget Necessary? A budget for future operations has been found wise, because it not only *defines* and *classifies* the *nature of expenses,* which broadly outlines direction of operation, but, particularly, it acts as a measure of what is to be done and *establishes a limit of financial outlay.* In the latter sense, it establishes an appropriation for future operations, and acts as a means of cost control.

The budget as a means of expense control has proved to be of such pronounced value that, today, every modern business concern operates throughout the calendar or fiscal year, or part thereof, on the basis of a budget established by the management of the concern at the beginning of the period.

Efficient operation is, of course, the ultimate objective of any budget. Experience has shown that it is much easier and far cheaper to correct errors that appear in plans laid out on paper, than it is to correct errors which appear after accomplishment. No group of contracting engineers would proceed with a project without carefully worked out plans and cost estimates. All construction projects are based upon budgetary estimates, for only in this way can the cost, price, and date of completion be established for the contract. The budget, thus created, establishes the limit of cost, which in turn determines the final amount of the contract covering the project, including profit on the undertaking.

In a similar way, no group of business men would start an enterprise, or attempt to administer it, without establishing an expense program to be effective as a "yardstick" for future operations.

The budget is a necessity in modern business.[14] It reveals weak-

[14] Some startling examples of the value of budgetary control occurred in viewing the plans followed by some foresighted corporations in the fall of 1929, when establishing their budgets for the following year. The country was entering what proved to be the most severe business depression it ever experienced. A few leading companies, in examining business conditions and estimating for the future,

nesses that might otherwise be overlooked. It tends to prevent over-expansion in times of prosperity, and lack of maintenance in depression periods. It shows what has been done, what is being done, and what should be done. It offers a guide for the industrial executive, and a check on the soundness of his previous decisions and plans.

The most outstanding advantage of budgetary planning is the checking of actual against theoretical performance throughout the budgetary period, and the "post mortems" at the end of each period. This gives a definite control over operations, and points out weaknesses and failings to the executives who head the various divisions.

Another point in favor of budgeting is the planning it necessitates. A concern that is planning six months ahead, or perhaps a year, is less likely to be caught short on materials or labor or productive capacity during a period of business expansion, and by the same token, a decline in business is not likely to find such a concern with overly large inventories on hand.

Budgets are also of value in the coordination they enforce between departments. They reveal the relation of one department to another, and show the executive where the performance of one division may be lagging behind the others.

The one great limitation to budgets lies in the tendency of many to regard them as a control or a form of management itself. They are not. A budget is nothing but a tool, and as such should be looked upon as an aid to intelligent management, and nothing else. Sometimes the system of budgeting becomes so involved that its benefits are largely counteracted by the maze of red tape that springs up. There is the classic example of the young married couple who said, "Our budget is really wonderful. We spend so much time each evening trying to balance it, that we never are able to get out and spend anything."

The purposes of the budget may be summarized in this way:

1. To establish, for an enterprise, a definite cost and profit objective of performance, for a selected period of time.
2. To find out what funds will be required for a given set of operations, from what source they will come, and when they will be needed.
3. To create an acceptance of policies and plans by all interested, and secure their cooperation toward accomplishment.

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saw little business in sight and therefore established expense budgets accordingly, then proceeded to trim expenses at every hand to meet anticipated conditions. Financial losses, in most instances, could not be avoided without a complete depletion of valuable personnel, but such losses were kept down within reason by adopting restricted expense budgets, and living up to them.

4. To determine, definitely, limits which will confine expenditures.

5. To set up a basis of comparisons and checks, which will indicate, with the passing of time, the cost of operating performance.

6. To guide changes to be made in current operations necessary to planned objectives.

Varieties of Budgets. The commonest forms of budgets used in industry are the *master budget*, which covers the entire operating budget for an enterprise for a given length of time, such as a year; and the *financial budget*, which deals with matters of receipts and expenditures, and which guides the treasurer in his financial operations. For instance, the master budget for a concern will show operations, perhaps, which require considerable outlay for improvements or sales promotional activities, with little coming in immediately in business volume to support this expense. The financial budget will show the volume and time of funds needed, and the volume and time of funds available, without any particular reference to the purpose of expenditures and receipts.

For the manufacturing enterprise, the master budget will cover the entire scope of the company's expenditures for a given period of time. It will be the sum total of a number of divisional or departmental budgets, and will be based upon an anticipated rate of operation, interpreted from business forecasts into actual items of expense such as wages, materials, and fixed expenses. It will also include the cost of extensions or improvement to plants and plant equipment, additions or redesigns pertaining to the product built, or sales and research programs constituting new undertakings. Thus, we see that the items going to make up the budget vary as to the kind of expense, and also as to whether the expense is for the continuation of existing property and operations, or the addition of new ones.

For large manufacturing or operating companies, the budget is built up from a number of divisional or departmental budgets, which, in turn, are composed of a large number of items. For instance, a manufacturer of industrial equipment would set for the period a "bogey" or estimate of sales to be booked, and starting from this point estimate profits to be made. Individual and even departmental budgets would be prepared for each phase of the company's activities, including the principal operations covering design, production, purchasing, accounting, distribution, and administration. Each of these departmental budgets would, in turn, include numerous items covering fixed charges such as light, heat, power, depreciation, and rent, and variable charges such as wages, materials, and supplies. All departments would have

to include in their budgets a share of the overall company expenses due to the cost of such items as administration and taxes.

The financial budgets for an enterprise will depend on such factors as the length of time required to turn over capital. For the builder of heavy machinery, many months may elapse after outlay for materials, labor, and overhead, before collection of funds is accomplished. Again, money may be borrowed, and debts become due.

The creation of the budget is based upon a familiarity with the various items of cost which make up the total expenditures of an enterprise or project. As has been seen, costs fall into a variety of classifications, but there are generally two main groups—those representing fixed expenses which change little with the extent of operations at a given time, and variable expenses which change materially with variations in the extent of operations. Insurance, depreciation, and rents, for instance, are considered as fixed expenses for a manufacturing enterprise, since they vary little from year to year. On the other hand, expenditures for materials, labor, and transportation may vary greatly with the volume of business done from month to month.

Furthermore, the creation of budgets will depend upon what operating expenses have been in the past; at least past operations will serve as a measure to guide the cost of future operations, and where possible accomplish greater efficiency in operation. Future plans, which may differ in nature and extent from past operations, also are a factor in determining proposed future expenses or budgets. The manufacturing enterprise may plan to add facilities or develop new products to sell, in which case budgets are created in such a way as to include these proposed expenses.

How is the Budget Prepared? There is no set rule as to who shall prepare the budget in an organization. Most larger companies establish and work through budget committees headed by a budget officer, who is usually an executive of the company such as comptroller, assistant to the president, or treasurer. Committee members often are heads of operating divisions or departments. The budget organization, thus created, is responsible for the *preparation*, *approval*, and *enforcement* of the budget. This responsibility points to the necessity of a budget officer, in every case, who is in close touch with the executive side of the company. The budget officer, working between his budget organization and the operating heads, is the one responsible for the budget itself and its administration.

The budget is based, primarily, on estimates that depend for their accuracy upon experience, good judgment, and accurate information. Forecasts of sales must be followed by accurate estimations of pro-

duction, materials, and labor needed, as well as plant requirements. From these, estimates of expenses are compiled, as well as estimates of receipts and payments, anticipated profit and loss, and the anticipated balance sheet for the budget period. The great need for a responsible officer and authentic information in the budget organization can thus be seen.

The mechanics of preparing a budget differ with methods and budget organizations, but an excellent outline of one manner of attacking the problem is given by Thomas B. Fordham and Edward H. Tingley in their book "Organization and Budgetary Control in Manufacture" (The Ronald Press Company, New York, 1924, p. 143). It follows:

1. The general manager determines the percentage of profit which is desired and which can be expected upon the capital invested in the busi-

2. The comptroller analyzes the costs of the product, the market, the past expenses of doing business; sets a quota of the product which must be sold; allots the amounts of money which can be spent by the various divisions, the result of which will be the profit desired.

3. The comptroller gives to each division head the estimates he has devised to cover the activities of that division. Then each division head breaks them down into the departmental needs and expenses when operating under the estimated schedule. Each department's expenses are carefully estimated and the total for that division should equal the allotment given by the comptroller.

4. If the division head believes that he cannot do his full duty and operate within the amount allowed for the expense in the estimates of the comptroller, he takes up the matter with the comptroller and arranges an adjustment.

5. When all divisional budgets have been adjusted and summarized, the final figures are given to the general manager, who approves them if satisfactory and authorizes each division to proceed accordingly.

6. Each division cooperates in its plans with the other divisions and schedules of production are made to coincide with the estimated sales

7. Items of expense are closely watched and efforts made to operate each division so that the actual expense is kept within the allotted limits.

8. The comptroller compiles a periodical (monthly or quarterly) profit and loss statement in which he sets forth the receipts from the sale of the product, the expenditures made by the various divisions of the business and the resultant profits, if any. This is placed alongside the estimated budget figures in a form for ready comparison.

9. This report from the comptroller is sent to the general manager

who reviews it and asks an explanation where any items of expense exceed the allotted amount.

It will be noted that here the comptroller is the budget officer. Naturally, many of the duties outlined are done with the assistance of his budget organization or committee. The outline is typical of the procedure for a manufacturing company. For a construction company or railroad, many items would be different, but as a whole, the same general scheme would be followed.

Although a budget is prepared in advance of its use on an estimated set of conditions, these conditions may change, and, for that reason, no budget should be *inflexible*.[15] One method of introducing flexibility into a budget is to make it on both a yearly (or long-term) and monthly (short-term) basis. The long-term budget does not go into detail, but gives a broad view of the anticipated expenditures and incomes of the various phases of the business, along with the anticipated year's business as a whole. The short-term or monthly budgets simply supplement the yearly budget by going into detail on the allowances for each phase of the business, but, being of such short duration, they can be easily revised and allowances made for fluctuations and changes which occur monthly or seasonally, but which are unpredictable over a long-term period. It should be carefully noted, as emphasized before, that budgets are used only as tools for the conducting of business and betterment of an organization. Hence, should unpredictable circumstances arrive which completely cancel a budget's worth, previous estimates should be discarded and new ones made immediately to fit the conditions better. A budget must never stand in the way of progress, but be changed to assist in that direction.

It has been pointed out that variable items enter into operating budgets. Incoming business might suddenly expand beyond that anticipated and provided for in the budget. This increase would require a material increase in expense for labor and material. If there were a fixed allowance for such items in the budget, and the budget were strictly adhered to for the period, it is obvious that profitable incoming business would have to be refused for the sake of adhering to the budget, which is a foolish procedure. Such conditions as this have led to the adoption of variable expense factors in the budgetary system. Instead of fixed amounts being established for variable items in the budget, these items are made flexible as to amount and depend upon a

[15] Reference: "The Variable Budget in Management by Exception," Fred V. Gardner, *Factory Management and Maintenance*, November, 1937, p. 67 (Part I); December, 1937, p. 63 (Part II).

UNION PACIFIC RAILROAD COMPANY

GENERAL BALANCE SHEET—ASSETS
DECEMBER 31, 1937

Investments:	
ROAD AND EQUIPMENT	$959,461,224.64
Less:	
Receipts from improvement and equipment fund	$23,823,091.13
Appropriations from income and surplus prior to July 1, 1907, credited to this account	13,310,236.52
Total	$37,133,327.65
Investment in road and equipment	**$922,327,896.99**
DEPOSITS IN LIEU OF MORTGAGED PROPERTY SOLD	$827,555.59
MISCELLANEOUS PHYSICAL PROPERTY	7,702,227.73
Total	$8,529,783.32
Investments in affiliated companies:	
Stocks	$20,363,886.91
Bonds, notes, and equipment trust certificates	11,710,859.36
Advances	19,527,877.86
Total	$51,602,624.13
Investments in other companies:	
Stocks	$81,160,708.06
Bonds, notes, and equipment trust certificates	65,765,779.95
Total	$146,926,488.01
UNITED STATES GOVERNMENT BONDS AND NOTES	$19,759,318.17
SINKING FUNDS	$100,000.00
Total Investments	**$1,149,246,110.62**
Current Assets:	
CASH	$9,739,058.20
TIME DRAFTS AND DEPOSITS	....
SPECIAL DEPOSITS	51,045.44
LOANS AND BILLS RECEIVABLE	6,447.50
TRAFFIC AND CAR SERVICE BALANCES RECEIVABLE	3,352,663.65
NET BALANCE RECEIVABLE FROM AGENTS AND CONDUCTORS	1,024,846.24
MISCELLANEOUS ACCOUNTS RECEIVABLE	4,940,042.27
MATERIAL AND SUPPLIES	30,498,241.56
INTEREST AND DIVIDENDS RECEIVABLE	963,756.92
RENTS RECEIVABLE	114,433.17
OTHER CURRENT ASSETS:	
Baltimore and Ohio Railroad Co. capital stock applicable to payment of extra dividend of 1914	113,875.70
Miscellaneous items	1,080.96
Total Current Assets	**$50,805,491.61**
Deferred Assets:	
WORKING FUND ADVANCES	$259,598.28
OTHER DEFERRED ASSETS	3,947,751.53
Total Deferred Assets	**$4,207,349.81**
Unadjusted Debits:	
RENTS AND INSURANCE PREMIUMS PAID IN ADVANCE	$20,249.75
DISCOUNT ON FUNDED DEBT	731,604.56
OTHER UNADJUSTED DEBITS	1,232,321.67
Total Unadjusted Debits	**$1,984,175.98**
Grand Total	**$1,206,243,128.02**

FORTY-FIRST ANNUAL REPORT—1937

GENERAL BALANCE SHEET—LIABILITIES
DECEMBER 31, 1937

Capital Stock	
Common stock	$222,302,500.00
Preferred stock	99,602,980.79
Total Capital Stock	$321,905,480.79
Funded Debt	354,963,010.00
Total	$676,868,490.79
Grants in Aid of Construction	$4,754,683.37
Nonnegotiable Debt to Affiliated Companies	$5,375,706.75
Current Liabilities:	
Traffic and car service balances payable	$1,236,791.98
Audited accounts and wages payable	9,588,005.63
Miscellaneous accounts payable	804,399.26
Interest matured unpaid:	
Coupons matured, but not presented	84,168.31
Coupons and interest on registered bonds, due first proximo	4,032,140.20
Dividends matured unpaid:	
Dividends due but uncalled for	117,034.46
Extra dividend on common stock declared January 8, 1914, payable to stockholders of record March 2, 1914, unpaid	122,851.76
Dividend on common stock payable third proximo	3,334,365.00
Funded debt matured unpaid	98,175.00
Unmatured interest accrued	1,636,003.07
Unmatured rents accrued	371,945.03
Other current liabilities	272,111.09
Total Current Liabilities	$21,697,990.79
Deferred Liabilities:	
Other deferred liabilities	$8,043,174.13
Tax liability	7,776,109.00
Total Deferred Liabilities	$15,819,283.13
Unadjusted Credits:	
Premium on funded debt	$98,668.87
Insurance reserve:	
Reserve for fire insurance	8,020,482.62
Reserve for depreciation	111,661,138.44
Other unadjusted credits:	
Contingent interest	2,179,910.60
Miscellaneous items	2,844,370.51
Total Unadjusted Credits	$124,804,571.04
Total Liabilities	**$849,320,725.87**
Appropriated for additions and betterments	$30,733,178.01
Reserved for depreciation of securities	34,972,570.88
Funded debt retired through income and surplus	667,788.66
Sinking fund reserves	100,000.00
Total Appropriated Surplus	$66,473,537.55
Profit and Loss—Credit Balance	**250,883,664.86**
Total Surplus	$317,357,202.41
As this consolidated balance sheet excludes all intercompany items, securities of the Los Angeles & Salt Lake Railroad Company and The St. Joseph and Grand Island Railway Company owned by other System companies are not included. The difference between the par and face value of such securities as carried on the books of the issuing companies (less unextinguished discount on the bonds and discount charged to Profit and Loss but added back in consolidating the accounts) and the amounts at which the securities are carried on the books of the owning companies is set up here to balance	$39,565,199.74
Grand Total	**$1,206,243,128.02**

ratio or percentage of total business done. Thus with flexible items in the budget providing for expeditures which vary with volume, expenses are held in a proper ratio to receipts.

Some companies pursue a practice of recalculating the entire system of budgets at short intervals to make them conform to current conditions. Formulas are generally employed, by which the budget allowances are revised to fit changing market conditions, wage scales, commodity prices, and other such variations. Such arrangements of flexibility are the only sensible systems of budgeting. To refuse to increase selling expense allotments and production allotments in the face of an unexpected increase in market activity would, indeed, be a foolhardy application of budgeting.

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Klein, "Getting the Most Out of Budgeting Control," *Iron Age*, February 9, 1939, p. 33.

A. A. Hadden, "Job-Order Plants, Too, Can Budget," *Factory Management and Maintenance*, September, 1938, p. 62.

CHAPTER VIII

THE REQUIREMENTS OF THE USER

THE ULTIMATE PURCHASER

It might appear more logical in our study of the economics of technical products to start with the product itself and follow it through to the user. However, design, manufacture, and distribution are all arranged to give satisfaction to the *user* through service. Likewise, the economic unit is supported by *consumption,* and any manufacturing or service-producing company depends for its existence upon its *customers.* It is most important, then, that we understand the interests and characteristics of the ultimate purchaser, and it is with reference to him that this chapter has been written.

The demands that are made upon a supplier are dependent upon both the class of ultimate customer with whom he is dealing and the equipment that he is to supply to this customer. It is necessary, then, to make a study of both product and user in arriving at the requirements of the ultimate purchaser. Goods may be of many varied classifications, and the requirements demanded of them by the ultimate user are still more varied. Only by a knowledge and accurate definition of these classifications is it possible to state intelligently what the ultimate user will require. Important, likewise, are the many points which the ultimate purchaser considers before he makes his decision whether to buy or not to buy, or what to buy. Various classes of purchasers will hold different viewpoints in buying. Such matters will be considered in this study of the requirements of the ultimate user.

CONSUMPTION

Consumption is one of the big factors in the study of the requirements of an ultimate user, and it is necessary to define accurately just what it is. We know that production has for its final object the supplying of products or services to meet the needs of the ultimate user or consumer. Where production *creates utilities,* use or consumption *destroys them.* When goods are destroyed for no good reason or service, then utility is lost, but when goods are destroyed to create that

satisfaction which they are able to produce, we say they are consumed —even though the process of consumption may extend over an appreciable period of time.

Habits of consumption are constantly changing. In days past, people guarded their consumption carefully and made things last just as long as possible. It was thought good sense to buy a buggy, suit of clothes, or a simple tool with careful consideration of how long it would last if given good care or proper maintenance. Today, consumption is not guarded so closely, because of a constant desire to have the best and latest and because of the constantly changing and improving products.

This change in the habits of consumption and in the requirements of the user has, in a few cases, been uncalled for, but in the field of capital or durable goods, especially, it has served to raise the standard of American living greatly—for which the change must be commended. True enough, many people live beyond their means in trying to keep pace with their neighbors: for instance, in wearing only the latest styles, possessing the latest household gadgets, or having the largest number of cars; but, on the other hand, this urge to keep up with the others has accounted, to a great extent, for the rapid acceptance of our modern forms of power, transportation, and communication; and their rapid acceptance has resulted in their being furnished at cheaper rates —all of which makes these services and products available to still others farther down the wage scale. Thus has the change in consumption habits raised our standards of living a great deal and served to make life fuller, according to accepted standards, for more people.

CLASSIFICATION OF GOODS AND PRODUCTS

With goods and services continually increasing in number and variety, and the various classes of purchasers likewise growing more numerous, it is not a simple matter to classify them all accurately. Such classifications as have existed relate to the goods themselves, the [illegible] which exists for them, or to the methods of distribution.

[illegible] we may speak of machinery and equipment as relating to a class of product, yet at the same time some items of apparatus included in this category may also be classified according to the particular market, as for instance, household appliances, because they form an item for use in the home; or, again, they might be classified as merchandise, because they are sold through merchandising methods. It is seen, then, that the classification of goods is an involved and [illegible] problem, to say the least.

Some general classifications of products will assist the engineer in obtaining a better conception of the various groups of products and purchasers. In order to understand the various classifications and the basis of each, the following classes will be defined and elaborated upon somewhat:

1. Capital goods, as related to consumption goods—a basic classification concerning the goods themselves and also their use.
2. Raw material.
3. Semi-manufactured products.
4. Manufactured or finished products.
5. Industrial equipment.
6. Supply equipment.

In each of these classifications are represented goods upon which definite requirements are made by the ultimate user, and it is important that the engineer be able to recognize the characteristics of these classifications.

Capital Goods vs. Consumption Goods. All goods can be divided into two general classes measured by their *permanency*. Briefly, these may be termed "capital or durable goods" and "consumption or perishable goods."

Capital or durable goods have a high degree of permanence, and are purchased as an investment with the idea that a return from them will extend over a considerable length of time. In this class might be included buildings, bridges, locomotives, power plants, ships, factories, machinery, and permanent household and farm equipment.

Consumption or perishable goods are those which immediately or soon pass out of existence in the hands of the user, such as food products, clothing, gasoline, coal, oil, and chemicals.

It may be difficult to draw the line between the two classes in respect to certain products. This is particularly true because the rapid progress in improving certain classes of durable goods causes them to be "outmoded" long before they are "outworn." Items such as automobiles, household appliances, and household heating systems fall into this class, but they should still be considered capital or durable goods, in spite of the fact that there is a distinct tendency to replace them before they are worn out, owing to rapid improvements and the pressure of sales promotion in making us "style conscious."[1]

[1] One of the most striking examples of rapid replacement of durable goods is found in commercial airplanes. Today, advancement and improvement of airliners are so frequent that airplanes on commercial airlines are being retired from service not because they are worn out, for no machine receives better

Durable goods are usually classed as a capital investment, though they depreciate in value as time elapses. Consumption goods are those which are looked on as constituting "running expenses" and must be continually replaced.[2]

Other than the general considerations that have been stated, there is really no definite rule by which we can define the difference between capital or durable goods and consumption goods. Goods have been arbitrarily classified, sometimes, as durable goods if their life is more than four years, during which time they are capable of meeting the requirements of the user. Such limits between the two classes of goods are purely arbitrary, however, and exceptions are sure to exist. An automobile might last for twenty years or more if it were run but five thousand miles per year—and then again, it might last but twenty months if operated five thousand miles per month. Certainly it is not true that, in the former case, the car is durable goods whereas in the latter it is consumer goods as our four-year definition would indicate.

Raw Materials. All goods or products may again be classified according to the *amount of processing* to which they are subjected.

Raw materials are those which exist in their natural state, examples being iron ore, coal, cotton, logs, crude oil, and rubber. No appreciable amount of labor has been expended upon them. For raw materials requiring mining and lumbering in order to free them for use, labor is, of course, necessary, but it is hardly considered processing labor. Raw materials are, therefore, that class of goods upon which there must be performed the greatest amount of processing before they arrive at a stage of consumption. Frequently, raw materials in the industrial world assist in the manufacturing of consumable goods, rather than being produced primarily for direct consumption.

The source of raw materials is important in more ways than one.

e, but simply because they are outmoded and because "competition in service" is so severe among the principal airlines that each is scrambling to be first with the newest and most modern ships. As improvements become less frequent, this high retirement rate will probably come down, since planes are built to operate much longer than style has dictated.

[2] For the individual, a home represents a capital expenditure—likewise a new heating furnace, mechanical refrigerator, or washing machine, but the food consumed or the clothes worn are items of current expense.

The railroads buy locomotives, coaches, and track-maintenance equipment, which are a part of their capital, but the supplies such as paint, lubricants, and fuel are included in the expenses of their operation.

The textile mill installs a new group of looms which also is a capital expenditure, but the electricity that is bought to operate them is a current expense.

Often it determines the location of an industry, especially if materials are the type that lose considerable weight in processing and bear a high transportation rate—in which case it is advantageous to locate the processing plants near the source of raw materials, if sufficient power and labor are available there. Raw materials often are difficult to secure, or are obtained only from foreign lands. They are a class of goods that must be given great study by the engineer in setting up a manufacturing or processing unit.

Raw materials are generally purchased in large orders. Those originating in the forest or the mine are generally purchased directly from the producer, although middlemen like selling agents and brokers are sometimes advantageous if the raw materials are widely scattered or available in many grades and forms.

Semi-Manufactured Products. Another class of goods that is classified by the amount of processing which has been done upon it is semi-manufactured goods.

Semi-manufactured products are those which have been processed and are available for manufacture into finished products, such as pig iron, steel, lumber, spool cotton, fabric, bolts, and paint. The characteristics of such products are usually indicated by specifications including such items as dimensions, weight, and chemical analysis.

Thousands of other examples of semi-manufactured goods may be found in industry, today, since any part, or any product, which is finished in itself but is yet to go into and become a part of another product, falls in this classification. For instance, even the completed generators and valves and ignition systems are really only semi-manufactured goods when they are yet to go into an automobile as component parts of that product. The parts that are made up for a new refrigerator, such as the motor, compressor, pipes, and freezing trays, are all semi-manufactured products because they are destined for further processing before they are ready for their ultimate use. Such processing consists of assembly.

Semi-manufactured products are often purchased from a source outside the concern that does the final processing which makes them usable. For instance, a manufacturer may make all the screws, nuts, bolts, and washers that go into his product, but the chances are that he will buy them from a concern specializing in their manufacture. Likewise, washing-machine manufacturers may buy the motors and other electrical equipment from specialists in these lines. The manufacturer must make certain that the semi-manufactured products that he buys are of as good a quality as he intends his final product to be.

Manufactured or Finished Products. Such products are the final and ultimate class in considering our classification of goods. Manufactured or finished products are those which have been *completely processed or fabricated,* and are ready for final use, without the expenditure of further labor other than that required to locate them so as to be used.

There is little need for examples of such products since anything that may be bought ready for use falls in this category. The automobile that we purchase is completely processed to the last operation, and is definitely a finished product. When a mechanical refrigerator is purchased and put in place, we have only to plug it in to the power supply, fill its freezing trays with water, and it goes to work. The problem of properly situating a new machine tool may be more complex, but the product is just as much complete and finished as the automobile or the refrigerator, and hence should be classed among the manufactured or finished products.

The manufactured or finished product may be the result of processing many *raw materials,* and may have in its make-up many *semi-manufactured products,* all of which have been brought to the point of playing a definite part in being useful.

Industrial Equipment. *Industrial equipment* usually includes the large variety of items which are needed to perform the various functions of manufacturing and distributing. In this class may be included machinery of all sorts, trucks, ventilating apparatus, adding machines, and so on. Similarly, the terms *agricultural equipment, household equipment, mining equipment,* and *transportation equipment* signify products based upon their fields of use.

The main difference between equipment and semi-manufactured goods is that equipment (whether it be industrial, agricultural, household, mining, transportation, or what not) is used to assist in further production, but still does not become a part of the finished goods, while semi-manufactured goods go to make up a permanent part of the finished product.

Despite the fact that equipment does not become an actual part of a finished product, it is no less important in the building of good products or the rendering of good services; and the better and more complete the equipment, the better should be the finished product or ice. It is very necessary, then, to choose carefully all productive and to make certain that it is adequate and always avail- for use. This is but another function for the engineer to study in his analysis of tech

Supply Equipment. Supply equipment usually includes minor items which are found necessary in processes or in the maintenance of equipment, such as belting, hose, wire, hacksaw blades, hand tools, cable, lubricating oils, electrical plugs, sockets, and lamps.

Some similarity between supply equipment and semi-manufactured products appears, if one considers as supply equipment some of the parts that were enumerated as semi-manufactured products destined to become component parts of the finished product. However, the semi-manufactured parts usually refer to parts which become a fixed part of a finished product. Supply equipment might be termed auxiliary equipment, in a sense, whether it becomes a part used in some of the processes of production or serves merely for maintenance of equipment.

TECHNICAL PRODUCTS

Technical products are a class of goods that must be given much thought and consideration since they represent so wide a variety of products of various subclassifications.

Technical products may be defined as those products which require in their design, manufacture, maintenance, and distribution a high degree of engineering skill.[3] Such a definition should be qualified, however, by the statement that in recent years a substantial share of technical products has been sold to the individual, and as such has been merchandised much in the same way as consumer package goods, no high degree of engineering skill being required in the actual marketing. For instance, domestic mechanical refrigerators, washing machines, automobiles, radio receiving sets, and oil burners, although technical products requiring engineering skill in design and production, have become so common and acceptable that their distribution falls into the class of merchandising specialties, little more complex than that of house furnishings.[4] Engineering skill in design and manu-

[3] Reference: "Changing Demands on the Technical Graduate; Design, Servicing, and Selling Technical Products," by B. Lester, *Journal of Engineering Education*, January, 1937, p. 422.

[4] How often we have heard such joking remarks as—"He bought that car because it has a new-type cigarette lighter—or a split windshield—or good-looking upholstery"—or some other such trifling item. And yet, how true it is that cars are today all taken pretty much as a matter of fact with little regard for performance by many prospective buyers because they have learned to have confidence that cars are all built well, and are efficient and roadworthy. It remains, then, for many to be "sold" on such trifles as those mentioned or perhaps by outside appearance of the machine or even by a pleasing answer to the question—"How much will she do?" Such traits are actually found among prospective automobile purchasers today, even though the machine they are contemplating is highly technical in itself.

facture has been responsible for this to a considerable degree by furnishing a product which is extremely simple, efficient, reliable, and attractive.

Classification of Technical Products. Man, in his primitive state, obtained from his natural surroundings his simple wants in their natural state. Civilization has diminished the availability of these elements in a pure state, and much of our equipment today is necessary to regain them, or to furnish them to meet our artificial needs. The furnishing of clothing, water, food, and light constituted, until the present century, a considerable share of our demand for technical products, but to these have been added, through the skill of the engineer, a continually expanding list for a multiplicity of services.

So many and so complex have become our demands that it has been felt wise to classify technical products in order to study and understand them. Below are listed the principal classes of machinery, equipment, and appliances constituting technical products:

- Household appliances:
  - Heating, cooling, and ventilating system appliances.
  - Refrigerators.
  - Clothes washers.
  - Clothes ironers.
  - Electric and gas ranges.
  - Dish washers.
  - Sewing machines.
  - Radio receiving sets.
  - Vacuum cleaners.
  - Cooking and heating appliances, etc.
- Small tools and service appliances:
  - Portable tools.
  - Car washers.
  - Gasoline pumps, etc.
- Office and shop appliances:
  - Writing machines.
  - Cash registers.
  - Calculating and sorting machines.
  - Reproducing machines.
  - Food grinding and slicing machines, etc.
- Professional and trade appliances:
  - Surgical
  - Clothes
  - , etc.

Agricultural machinery:
- Soil preparation equipment.
- Harvesting equipment.
- Sorting, grading, spraying equipment, etc.

Power machinery:
- Steam turbines and engines.
- Internal-combustion engines.
- Water wheels.
- Boilers, condensers, stokers, powdered coal and oil burning equipment.
- Electrical generators, transformers, switchboards, control, etc.

Construction machinery:
- Shovels and dredges.
- Hoists and derricks.
- Concrete mixers, road machinery, etc.

Transportation machinery:
- Automobiles.
- Trucks, buses, street cars, etc.
- Locomotives of all types.
- Marine equipment.
- Airplanes.
- Elevators.

General Industrial machinery:
- Machine tools.
- Woodworking machinery.
- Pumps.
- Compressors.
- Fans and blowers.
- Refrigerating machinery.
- Electrical apparatus.
- Material handling equipment.
- Foundry machinery.
- Dust collecting, heat treating, humidifying equipments, etc.

Specialized industrial machinery, peculiar to the processes of specialized industries:
- Coal and metal mining.
- Chemical plants.
- Food processing plants.
- Paper and pulp mills.
- Textile mills.
- Cement, rock, and clay-working plants.
- Rubber and leather manufacturers.
- Printers and publishers.
- Steel mills.

Interests of the Engineer. In the field of technical products, the engineer is found to be interested both in *capital goods* and in *consumption goods.*

The task of selecting the points of greatest interest to the engineer in the *capital goods* field is not a difficult one, since such goods require a high degree of technical skill from their creation to their distribution and installation. The interests of the engineer in capital goods relate to:

Design of the equipment or structure.

Manufacture or construction.

Distribution—where the product is that of equipment requiring engineering application service.

Operation and maintenance.

The engineer's interests in *consumption goods* relate primarily to development, processing, and manufacture, since distribution usually involves only commercial problems. In the public service industries, such as the manufacture and distribution of power or the furnishing of transportation, since the service rendered is of a highly technical nature, furnishing these services is usually directed by technically trained men. The distribution of such services, unlike most consumers' goods services and products, is highly technical, involving accounting practice, and a complicated rate structure requiring a high degree of technical skill.

The Purchaser's Interests in Technical Products. With the rough definitions of various classes of products before us, let us now examine the interests of the purchaser.

The engineer has always been qualified to take a great interest in technical products, which a generation or so ago were decidedly a mystery. The public knew little of the construction and operation of apparatus, and an understanding of it was left largely to the engi- Conditions have greatly changed since then, however, and ...tus has become a part of the life of the average individual. ... automobile, airplane, telegraph, radio, electrical and mechanical household appliances, and many other developments have had a profound effect. Our systems of production have brought vast armies of our people into manufacturing and servicing plants where they come into intimate contact with machinery. Other large groups are engaged in distribution, where they come in contact with apparatus and the reaction of people toward it. Through sales promotion and advertising, the public in general has been educated to recognize the technical characteristics of such products, and the ultimate user has learned by

experience and contact with apparatus both its characteristics and value.[5]

All these influences have brought people and products of a technical nature very close to one another. Not only have our habits of life been altered through the use of such products, but our attitude toward them has radically changed. Since we are in daily contact with them, those characteristics which concern human relationships, such as form, color,[6] quietness in operation, cleanliness, convenience, and safety, have come into prominence. No longer are the interests of the purchasers limited to technical performance.

Manufacturers of package goods have been quick to appreciate the value of eye appeal, shape, form, and color, in merchandising their products. Not only has this assisted in identifying the particular make of product, but also, through an application of the laws of psychology, an attitude and habit of mind favorable to the product have been built up in the mind of the prospective purchaser, so that a distinct desire for possession arises. When the purchase is made, the purchaser experiences a feeling of pride, which results in a particular interest in the purchase and undoubtedly causes it to receive the best of attention, thus adding to its life and usefulness.

An interesting example happened several years ago, when household equipment was emerging from the stage when it was regarded as "machinery" to the stage when it is regarded as an "attractive utility." Domestic electric washing machines were originally unattractive, unsafe, and rather unreliable. They employed exposed gears, shafts, belts, or chains for transmitting power from the crude electric motor

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[5] The degree to which one housewife had been educated in the technical products she uses was observed recently in a large electrical appliance store where numerous electric refrigerators were available. By reading the advertisements—and evidently by further and deeper study on her own part—the young wife not only was able to tell what refrigerant was used in each different make of machine, but she further had facts on the characteristics, advantages, disadvantages, and dangers of each. She was definitely in a more advantageous position to make a wise choice than she would have been had she no knowledge whatever of refrigerators and refrigerants. Naturally, this is not the rule, but it is evidence that, at least in part, the buying public is growing technically minded—much to its own benefit.

[6] Color is becoming of increasing importance in the acceptance of technical products for the home, office, store, and even the factory. One recent color preference study has shown, for instance, that men prefer blue, red, violet, and orange, in the order named, while women prefer red, blue, and violet, in that order. White or light-tinted shades are usually associated with cleanliness, and are often chosen for finishing equipment used in the preparation of foods.

Reference: "Designers Should Know Color Psychology," David Donovan, *Machine Design*, September, 1938, p. 32.

to the washing tub and wringer. One individual, unfamiliar with the business of building and selling electrically driven washing machines, seized upon the idea of building and selling a machine which, for the period, was considered beautiful. A company was organized which went into the business in a large way. A machine was designed and built employing much the same features as were put into other machines of the day, but the body of the machine was completely paneled and beautifully painted and decorated, carrying to the housewife the message of happiness in eliminating the drudgery associated in her mind with washing clothes. The machine was promoted by elaborate and beautiful advertising material.

After several thousands of these washing machines had been sold in a certain middle western city, a check was made upon several hundred housewives, selected at random, to learn the attitude of the individual purchaser toward the machine. It was found that in spite of the fact that in many instances some trouble had been experienced with the operation of the machine, the housewife had a surprising degree of pride in it, and invariably the machine had been treated more like a piece of expensive furniture than of basement machinery, and the greatest care had been taken in keeping it clean and neat. The washing machine had been displayed with pride to neighbors and visitors, and had evidently added greatly to the self-esteem of the purchaser.

Equipment not so closely associated with the individual has been going through this same process, and the work of the individual artist is seen in locomotives, buses, airplanes, ships, air-conditioning apparatus, office equipment, and now in factory equipment.

The purchaser's interests are, therefore, both *rational* and *emotional*, and an appreciation of the degree to which these factors predominate in the acceptance of a given product is vital to the engineer engaged in design and manufacture. Rationalism deals with factors of performance, whereas emotionalism deals with factors relating to personal acceptance. Pride in ownership is largely an emotional factor and depends to an increasing extent upon appearance as contrasted to performance of product.

It would probably be quite safe to assume that a great part of the buying of consumers' goods is done from the emotional and perhaps even habitual instincts. Most of us are prone to weigh none too seriously the more important factors that have to do with our purchases of consumers' goods since their value is not so great as that of durable goods and since, too, it is not so easy to delve into the more rational causes for our purchases of such goods. Also, we know

that we are protected, in many cases, by statute and in other ways as to the quality of goods consumed, especially in respect to foods and drugs. On the other hand, in the purchase of durable goods, as machinery and equipment, where too we are affected by emotional appeal, many buyers have no means of determining the quality of the product and can often be led astray by technical arguments purposely framed to mislead the uninitiated.

Examples of Purchaser's Interests. In order to illustrate and furnish suggestions for a further study of the various interests of the purchaser in different classes of equipment and machinery, we will select some typical examples.

In studying these, as well as other examples, it will be found that the interests of the purchaser[7] can usually be grouped under the following four headings:

1. Capacity, of the piece of equipment selected, to do the work or render the service for which it is intended.
2. Performance in operation.
3. General physical characteristics—characteristics having to do particularly with human relationships.
4. Price, terms of payment, availability, guarantee, service facilities.

It will be recognized that items 1, 2, and 4 are primarily interests aroused by rational reasoning and thinking, whereas item 3 is based on the taste and feeling of those who own and use the equipment. If all purchasers could be wise enough to employ both rational and emotional interests in their buying, they would undoubtedly be rewarded by a great deal of satisfaction with their purchases. One cannot buy on rational appeal alone, for, if the daily use of the item is not pleasing to the emotional instincts or senses, even superior performance cannot make up for this lost feeling of pride and satisfaction; this is especially true of an article used personally by the buyer. Naturally, the purchasing agent of a concern would not be seriously troubled by this factor, in industrial buying.

Example of a Machine Tool Purchase. Let us assume that the superintendent of a metal-working plant is in the market for a machine tool. He has already determined that it is economically wise to purchase a tool, and has decided upon the class of tool required.

The question before us takes the form: What are the most important factors that particularly interest the superintendent in de-

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[7] Reference: "If I Were a Buyer of Motors," J. W. Jessop, *Electrical facturing*, February, 1938, p. 29.

termining the make of tool to buy? We may realize that such a purchaser is very much more likely to allow his more rational interests to rule, and in the purchase of anything such as a machine tool it is well that this is so. The factors that will probably be of most interest to him are:

Performance factors:

Ability to handle materials to be machined.
Adaptability to other classes of work should requirements change.
Accuracy of work to be done.
Efficiency in the use of power.
Efficiency in avoiding loss of materials.
Efficiency regarding cost of upkeep.
Degree to which machine operates automatically.

Capacity:

Capacity to handle work intended.
Excess capacity available at some future time if needed.

Physical factors:

Weight, size, and shape—with regard to floor space, installation costs, and headroom.

Human relationship factors:

Safety of machine in use, protection against life, limb, and property injury or damage.
Cleanliness of machine in service.
Quiet operation.
Convenience of machine in hands of operator.
Attractiveness of machine—outline, finish, and color.

Conditions established by supplier:

Price.
Terms of payment.
Guarantee.
Availability.
Service facilities.
Supplier's reputation and record of performance.

If the superintendent were to be given a satisfactory and pleasing answer to each of these points of inquiry by some machine tool r, very likely there would be little reason for his needing to further for his machine. If there should be several competitors for this business, the machine tool dealer that offered the most satisfactory answer to each point brought up would probably be the favored supplier. A machine that is uncommonly attractive on a few of the points does not sell as well, perhaps, as the machine that is fairly attractive from *every* point of

Example of an Electric Household Refrigerator Purchase. We have just considered the factors that would probably be of greatest interest in the purchase of an industrial piece of equipment. Now, let us turn to equipment of a household nature and compare the factors of interest with those of the previous purchaser. It is assumed that a woman has decided to purchase a mechanical domestic refrigerator. If she were to purchase this appliance intelligently, she would consider such product characteristics as these:

Performance factors:

- Ability to produce and maintain suitable temperatures in food chamber.
- Ability to produce ice.
- Time required to obtain these operating conditions.
- Ability to prepare desserts, or other special services.
- Economy in the use of power.
- Degree to which the machine operates automatically.
- Freedom from repair or the need for maintenance.

Capacity:

- Capacity of food space.
- Capacity for making ice.

Physical characteristics:

- Weight.
- Size—floor space, height, and depth.

Safety:

- Safety from electric shock, from gas leakage, from food spoilage, from injury from projecting parts.

Convenience:

- Location of food chamber.
- Adaptability of food chambers for various shaped articles.
- Adjustable food shelves; doors easily opened and shut; illumination within food chamber; ease in removing ice; convenience in cleaning internally, externally, and the floor; ease of control and defrosting; indication of temperature; etc.

Quiet operation:

Beauty of outline—color and finish:

- Durability of finish.
- Resistance of interior to stains.

Conditions established by supplier:

- Price.
- Terms of payment.
- Guarantee.
- Availability.
- Service facilities.
- Supplier's reputation and record of performance.

It is recognized that an intelligent purchase of a refrigerator for the household is not too unlike the purchase of a machine tool for an industrial plant and that many of the same points should be brought out for consideration.

It would be an interesting experiment to analyze the points that the average housewife considers when she picks out her refrigerator and to see what percentage of purchasers—be they either men or women—really go about their purchasing from a logical viewpoint as outlined above. The data on such an analysis would probably show that a few do go about the purchase of a new refrigerator as systematically as this—like the young lady mentioned previously for her uncommonly full knowledge of refrigerants—but many more undoubtedly buy from the emotional urge of the refrigerator's streamlining, its effective advertising, or just because the neighbors are well pleased with one of the same make. However, the refrigerator is like the automobile in that it is now fairly well standardized in performance; hence the results of buying from purely emotional rather than rational interests are not at all disastrous since satisfaction is fairly well assured in most popular makes today.

Example of the Purchase of Trolley Buses. Let us consider a city that is changing from street cars, on its surface lines, to electric trolley coaches. What are some of the considerations that would interest city traction engineers, in the wise selection of coaches?

Performance Factors

Rating and characteristics of traction motors—speed; ability to maintain schedules; performance on grades; ability to withstand overloads; ventilation; lubrication; maintenance requirements; smoothness of operation; protection from dust, dirt, and weather; accessibility; ease of changing motors and gears.

Efficiency in the operation of coach.

Maintenance—ease of maintaining; frequency of maintenance required; cost of upkeep.

Useful life of equipment—how long will the motor, body, tires, and accessories last?

Ease of operation—in congested traffic; number of operators needed, performance in passing cars or on ascending and descending grades; ability to utilize small curb space for loading.

Acceleration and deceleration—smoothness; is it sufficient to maintain schedules? Is rate of acceleration and deceleration a hazard to traffic? To passengers?

Ability to withstand accidents—effect upon equipment of shocks from side, front, or rear.

Effect on other equipment—is coach damaging to trolley wires, trolleys, and other overhead equipment? Does operation cause radio interference? Is it damaging to street surfaces?

Lighting—is lighting dependent on trolley lines, or is it an independent battery system?

Heating and ventilation—what system is used? Efficiency and ability to provide sufficient warmth, fresh air, and healthful conditions. Ease in control of these.

Effect on power system—load; surges.

Capacity

Passenger capacity: What is ordinary seating capacity? Standing and seated rush-hour capacity? Capacity of overload in times of emergency and great congestion?

Physical Factors

Weight, dimensions, shape, headroom, legroom between seats, floor space, number of windows and doors.

Size of tires, batteries, and other accessories requiring replacement.

Human Relationship Factors

Safety—strength of body; safety devices for driver's use; safety doors to prevent accidents to passengers; shatterproof glass; brakes; emergency exits.

Noise of operation—is this disturbing to conversation? Are there disturbing noises which affect passengers or drivers? Do coach noises disturb residents?

Smoothness of operation—smoothness of starting and stopping; ease of riding under various street conditions; can passengers safely stand while coach is in motion, stopping, starting?

Convenience to passengers—ease of entrance and exit; height of steps in getting on and off; ability of coach to pull close to curb to discharge and take on passengers; convenience in paying fares or signaling driver.

Convenience to operator—ease of handling controls; convenient fare-collection facilities; control of doors; visibility; ease of steering and braking; auxiliary safety devices such as fog lights, windshield defrosters and wipers.

Attractiveness—good lighting; ease of keeping clean; accessories for passenger comfort as foot rests, arm rests, mirrors, ashtrays; attractive design both inside and out; color combinations possible.

Comfort—heating; scientific lighting; absence of odors; efficiency of heating and ventilation; cushions and upholstery; width of seats; legroom; headroom.

CONDITIONS ESTABLISHED BY SUPPLIER

Price.
Terms of payment.
Guarantee
Availability.
Service and renewal parts service.
Supplier's reputation and performance record.

DESIGNING EQUIPMENT FOR THE ULTIMATE USER

One of the most difficult problems confronting those who design industrial equipment is in accurately determining and interpreting the conditions under which the equipment will be called upon to operate. It is one thing for the engineer, in meeting the requirements of the user, to design a piece of equipment which will perform the particular functions or duty cycle for which it is intended, and another to provide in the design for all possible operating conditions which the equipment may encounter in the hands of a wide variety of users.

The designer of paper-making machines must consider all the conditions to be met with in the paper mill. For instance, aside from determining the exact mechanical requirements, he must consider matters of temperature, humidity, the skill and habits of paper machine operators, loss due to breakdown, ease of repair, and numerous other factors that relate to the particular kind of service to be met. In this instance, since the equipment is highly specialized and used in one industry only or by one class of purchaser, the designer can delve into the particular requirements of the paper mill, and design equipment to meet this one class of service.

On the other hand, an engineer who designs fans and blowers, which have a broad use in many industries, must consider not the requirements of one class of user, but many. He may find a wide difference in the requirements of different classes of users, and is at once confronted by the economic problem whether to make one type of design to meet a wide class of users, or different types of design for different classes of users. The fan and blower designer finds that the design requirements of fans and blowers for heating and ventilating installations for buildings are not the same as those for mine ventilation, or the handling of corrosive gases encountered in some chemical plants. He must determine where to draw the line, i.e., whether to design to take care of the worst or most difficult condition operation, in which case many of the units produced are of more borate and expensive construction than the particular service may or whether to design equipment for each major class of user,

thereby reducing the quantity of units produced for any selected class of user, with resulting increase in cost.

From a practical viewpoint, on the basis of what has taken place in the design and use of machinery and equipment in the past, the builder usually starts in business producing a line of equipment which meets a popular need. As he proceeds with production and distribution, he finds that the one line is not altogether suited for certain classes of users. Other lines are added, requiring design modifications, so that the builder finds, as his business develops, two or more distinct lines of equipment necessary.

A common illustration of this is found in electric motors. These were originally available only in the "open" or "self-ventilated" type. As the use of motors spread throughout industry, and their application to individual machines became more highly specialized, several types, depending upon conditions of service, appeared from the hands of designers. "Totally enclosed" motors became common, intended to withstand moisture and dirt. Later appeared "splash-proof" motors, "explosion-proof" motors and even "water-tight" motors, as well as other specialized types, all designed to meet a given set of operating conditions. Economic factors, particularly relating to physical size and cost, prevented the adoption of a design which would meet all conditions of operation, for it was still found that the requirements of the majority of purchasers could be met by the "open motors," which are the cheapest and smallest type available. The same condition exists in respect to many lines of equipment which have a wide range of demand.

The following conditions of operation, many of them unusual, are nevertheless ones encountered by experienced engineers who design equipment:

Rough Usage. Only by practical experience can those who design equipment appreciate what rough-and-tumble service equipment sometimes receives, from the hands of ignorant and careless users. Several years ago the designer of a portable air-driven reamer, used in structural work to ream holes prior to riveting, designed an efficient machine, only to find that it failed because the workmen, when through with it, dropped it to the ground. Most classes of equipment used in construction and mining operations get extremely rough usage and must be designed accordingly.

Atmospheric and Temperature Conditions. The designer must consider the extremes of moisture and temperature in all classes of equipment that he furnishes. The basis of rating, as in air-cooled Diesel engines, and the materials employed, as in electrical machinery,

are important factors. Particularly must these conditions be considered in connection with equipment to be used under tropical or arctic conditions.[8]

Gases and Foreign Materials. Often equipment is called upon to operate under conditions where corrosive gases are present or where foreign materials are plentiful. Equipment in many chemical plants must be specially designed; the same is true of textile machinery surrounded by lint-laden atmosphere, or equipment in foundries and cement plants where the air is laden with dirt.

Quietness. The perfection of appliances used in the office, store, and home has brought into prominence the importance of quiet operation [9] in all classes of equipment, and has encouraged fundamental studies [10] as to the causes, transmission, and elimination of sound. Users now give serious consideration to quiet operation, which formerly received little attention.

Safety. Of fundamental importance is the matter of safety to life and limb, for, with a constantly closer contact between apparatus and people, the user must be guarded against every possible danger. In years past, for example, numerous accidents have occurred in the operation of punch presses, for in the earlier designs it was quite possible for the operator to lose a finger or hand. With the increased demand for safety, and increased skill of the designer, the possibilities for such accidents have been practically eliminated.

Cleanliness, Appearance, Convenience, and Portability. Such matters as these are continually receiving greater consideration by purchasers of technical products, whether they be locomotives or electric shavers.

The demands of air travel and airplane design have called for equipment which is extremely light and compact, yet completely reliable in operation.[11]

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[8] It is very unlikely that the designer of refrigerators ever had such a use occur to him, but Byrd took a refrigerator with him to the antarctic—to keep *out* the cold and keep food *from freezing*.

[9] Reference: "Product Silence Has Its Price," *Electrical Manufacturing*, January, 1938, p. 19.

[10] The manner in which "noise" is analyzed in machinery today is an interesting and scientific process. A good article on noise analysis and the theory of noise measurements is found in "Analysis of Gear Noises Bring Practical Values," R. S. Davidson and L. J. Collins, *Machine Design*, December, 1938, p. 31.

[11] Motors and generators for use aboard transport airplanes are designed to weigh only 10 to 20 per cent as much as the conventional units of equivalent power output. This is made possible by changes in shape and materials, and improved design. In one instance, a 5-kw. direct-current engine-generator set complete with engine, generator, and control weighs but 130 pounds, while an equivalent commercial generator weighs 1200 pounds.

In the factory, the economic advantage of "good housekeeping" has been fully demonstrated, so that manufacturing men now demand those characteristics in equipment which will make possible a neat, attractive, and compact production shop.

Unusual Requirements.[12] For equipment used in various parts of the world, purchasers' demands may include features not ordinarily encountered in this country. Obviously, such matters as nameplate ratings and instructions must be written in the prevailing language, and perhaps the metric system. Some engineers have designed apparatus, including parts of wood and fiber, to find later that they had to be replaced by other materials on account of destruction from ants. Frequently, heavy machinery going to mines or power houses far from civilization must be designed in much smaller elements than ordinarily, in order to provide for transportation, which, in some instances, is nothing more than mule-back or airplane. Instances have occurred where highly polished or colored parts, attached to a machine, have had to be made plain and unattractive, to prevent natives' stealing them for adornments. Only through experience are *all* user requirements covered.

TECHNICAL SERVICES

We have considered technical products from the viewpoint of the service the finished product will render the user, as an operating mechanism. In doing so, we must not lose sight of the fact that what interests the user is not the apparatus itself, but the kind of service that it will render.

Maintenance. Equally important, then, is the matter of maintaining the apparatus in operating condition, and this factor, in itself, constitutes an important form of technical service.

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[12] "Pulling a ten-and-a-half-ton plow half a mile below the surface through all types of ocean bottom requires a tow line of unusual flexibility and strength. Ordinary chain is too heavy and cumbersome; steel rope, when subject to great strain, develops torque, or twist, and would overturn the plow. For this purpose a special one-inch nickel steel stud-link chain 4200 feet in length was developed. Each link in this remarkable chain, the strongest ever forged in one piece, is capable of withstanding a proof load of 84,000 pounds, with an ultimate strength of 117,000 pounds. The catenary curve of the chain, as it is suspended in the water from the ship, separates it sufficiently far from the cable to prevent the two from becoming entwined."—"Plowman of the Deep," *Saturday Evening Post*, December 24, 1938, p. 50.

The engineers of a large manufacturing company recently had the unusual task of designing and building a "time-capsule" capable of preserving various objects and records of present-day civilization for the inhabitants 5000 years hence. The capsule was buried in a 50-foot well and was constructed of a heat-treated alloy of copper, chromium and silver (Cupaloy), which is hard, strong and highly resistant to corrosion.—Reference: "'Time Capsule' is Cupaloy," *Machine Design*, October, 1938, p. 31.

Very few products are of value to the user without some sort of service rendered by the supplier. Many familiar examples will occur to the reader: for instance, the automobile, air-conditioning equipment, machine tool, and coal cutting machines. Since such products are useful only because they perform a service to the user, the user is interested in seeing not only that the equipment is furnished in an operating condition, so that it can immediately render that service for which it is intended, but also that facilities are available which will make it possible to continue in operation, without undue expense or loss of time. The user thus expects the supplier to make the product available to him, provide for its installation if need be, or at least show the purchaser how to install it, and, after the equipment is put into service, provide facilities so that it will continue to operate in its original condition when and where needed. A multitude of conditions may arise which may decrease or destroy altogether its operating usefulness and efficiency. The supplier must then provide a form of maintenance service, which must stand ready to give technical service at the time and place needed. The availability of such a service, which includes equipment parts for renewal purposes, goes to make up a complete form of service upon the product.

Since most equipment forms a part of a complete manufacturing or fabricating process, the user is interested not only in a form of skillful maintenance, but particularly in having this service immediately available to avoid losses which might extend far beyond the value of the particular piece of equipment.[13] Maintenance of equipment, in industry, is a service usually shared by the user and by the equipment supplier. Large manufacturing plants, such as cotton mills, will, themselves, have technical experts available who can repair and adjust looms, but, nevertheless, such users depend upon the equipment supplier to furnish correct renewal parts for the looms promptly. A small machine shop, on the other hand, will not have facilities for repairing a lathe, planer, or compressor, and must depend upon the supplier for this help.

and Contracting Services. Consulting engineers are usually employed by industry in rendering an advisory service, usually relating to plant or process, or both. Much of their work is of a specialized nature, relating to a particular class of work, as, for in-

[13] In many process industries, where the process proceeds from one machine to another, the failure of a single part of one machine may cause a loss which, in the space of an hour, will exceed several times the cost of replacing the

stance, designing a structure or the layout of a paper mill, power house, or water works. In many instances, such companies include both an engineering and a contracting service. The requirements of the purchaser of such services can be stated quite simply, for the purchaser's sole interests relate to the quality of the work done, the time in which it is accomplished, and the price to be paid for the service.

Public Service. The technical services discussed thus far have been those that necessarily accompany and are a part of a technical product's purchase. Technical services which are furnished complete in themselves constitute, for the most part, services relating to *transportation, communication,* and the *furnishing of power and water,* which are usually classed as forms of *public service.*

The users' interests in technical service relate to:

Its availability as to location and cost.
Its continuity,[14] frequency, or speed.
The price charged for it.

Technical equipment, usually of an elaborate nature, is required to render such forms of service. Being public in nature—that is, required by people and economic units—such services as these involve complex problems relating to ownership, operation, returns, and costs of service. With the advance in human standards and requirements, it is obvious that other forms of service will, in time, be included as public services.

Such a service cannot be entirely divorced from the products necessary to enable the purchaser to use it. For instance, the availability of gas and electricity is worthless, unless consuming appliances are available; and the public utility, in order to increase consumption of its services which in turn makes possible more satisfactory and less expensive service, has in the past undertaken promotion of the sale of such products.[15]

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[14] The dependency of the individual upon the continuity of various forms of public service is emphasized when we see the result of major disasters. Storms and floods, for instance, will place a community in total darkness, and, in a mechanized society such as ours, we find the home routine disrupted if heat, refrigeration, time, door-bell service, or even gasoline supply for automobiles is lacking even temporarily.

[15] One of the prevailing and dominant interests of every thrifty user is how to save money. The public utilities, public carriers, and others have been unusually active in promoting further use of their facilities by appealing to this emotional saving instinct of the public. More than one traveler has been influenced to take the train, because it is said to be cheaper than to drive one's

THE PURCHASER'S SELECTION

When a company or individual has decided to buy a piece of equipment, and is faced with the problem of determining which make of equipment to purchase, many influences have a direct bearing upon the selection. These relate to:

The merits of the particular piece of equipment, in regard to price, availability, or other equipment to which it must bear a relation.

The individual who is attempting to sell it.

The company making or selling it.

Trade relations, by which preference may be given to a particular supplier.

It must be admitted that the purchaser may be influenced in many ways toward reaching this decision to purchase, and producers may have a strong influence in helping him make up his mind to purchase at all.

In order to understand fully many of the problems of production and distribution of technical products, we must understand the principles of consumption. Much thought and study have been devoted to human behavior in purchasing, because, by a closer understanding of it, progress in selling is made. Human beings, in attempting to satisfy their desires, act impulsively, without being directed to the purchase; act according to established habits; or act rationally, carefully evaluating available evidence.

So far as the merits of the article that one may buy are concerned, the prospective customer can base his decision upon previous experience, the experience of others, and the information furnished by the manufacturer or supplier.

In respect to technical products, the industrial organization ordinarily uses the greatest intelligence in selecting and buying, because it is better organized to perform this function, has had more experience with technical products, and is less likely to be influenced by persuasive salesmen. Commercial and institutional buyers commonly use less intelligence and are more likely to be influenced by clever salesmanship than industrials, because, generally, unless they themselves are engaged in distribution or extensive use, they buy only occasionally.

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own automobile. Gas and electric utilities have cooking schools designed to show how economical and convenient gas or electric cookery is. A midwestern power company has hundreds of electric ranges in the homes in its territory on a rental basis which may be continued for any length of time—the rent being most nominal, the stoves all new at the time of installation, and there being no obligation to purchase.

The average individual shows less intelligence when buying technical products for his own use than business organizations. Often the purchaser is influenced to a marked degree by clever salesmanship, advertising, or idle conversation. Such factors as style and eye appeal influence him, and often he does not understand and is confused by the intricacy of technical features. As was brought out before, however, manufacturers and distributors are doing much to educate the public upon the construction and operation of technical products, and the buying intelligence of the average purchaser is steadily increasing.

SPECIFICATIONS

A specification is intended to give a complete description of a product, structure, or service, so that its characteristics may be determined in advance for the purpose of establishing conditions of sale, and ultimately satisfying the purchaser and the user. It usually consists of drawings showing appearance, dimensions, and construction, a list of materials required, and a complete description of functional operations.

Specifications, it will be remembered, were studied in Chapter V in their relation to standardization, and their general utility and form were considered there. The specification forms an important item in the requirements of the ultimate user, although its purpose for ordinary technical products is somewhat different from the conditions set forth in Chapter V, as we shall see.

In considering technical products in regular production, the original use of the specification has changed considerably with the advancement of standardization and familiarity with technical products. Years ago, an engineer might be retained by the user to prepare a set of design specifications, upon a certain item of apparatus, which was finally to serve as a guide for a manufacturer who might be selected to do the job. The manufacturer's responsibility was fulfilled when the item was built in accordance with the specifications. Today, the designer is usually a part of the manufacturer's organization, and working in close touch on one hand with the factory personnel, and, on the other hand, with customer requirements, the whole effort being coordinated. Standardization and quality manufacture have often made it possible, now, for the user to see the product, or a close approximation of it, before purchasing. Thus the specification itself, although as necessary as ever, is largely prepared within the manufacturer's organization for its own use, and that of the purchaser. For large machinery or a group of equipment designed to work to-

gether, however, the specification, as well as the independent consulting or contracting engineer, are important.

When we turn to structures, such as homes, public and commercial buildings, dams, and all construction work, the situation is very different. Public taste and varying conditions like location and climate do not permit of the standardization which applies to factory products. The engineer engaged in design operates independently in the preparation of the specifications, conferring with possible material suppliers and contractors, and the ultimate purchaser. The contractor undertakes to create the structure in accordance with the specifications at a price and within a given time.

We might well compare the factory and product to the ready-made clothing manufacturer and his standardized suits, and the engineer and contractor to the tailor shop.

When public money is to be spent, the specification is used extensively in an attempt to avoid favoritism to any one supplier, and to assure quality and uniformity to meet exacting conditions.

AGENCIES ASSISTING AND PROTECTING THE PURCHASER

For many products, such as foods and drugs, the individual purchaser has no means of determining the composition, and it becomes of vital importance that some public protection be given him against harm and deception.

Such protection is also important in respect to technical products. It relates particularly to the quality and price of the article, protection against property loss as by fire, flood, and explosion, and against bodily harm. As technical products have come to be used so universally and so often not exclusively by trained experts, much attention has been given to this subject by manufacturers, distributors, and various forms of government.

Happily, as business organizations become more stable and permanent, the commercial value of making products safe in the hands of the user under all conditions of operation which can be anticipated is being appreciated.

A few of the important agencies that have been at work to further public safety and make certain that installation and operation of technical products are according to standards and such that no serious may come of such products' operation are the following:

Federal and state laws relating to fair business practices; the Federal Trade Commission.

Standards set up by engineering societies and by trade associations of manufacturers and distributors of products.

The Board of Fire Underwriters, Bureau of Mines, United States Bureau of Standards, and others.

Public and trade associations representing industrial and individual users.

Whether it be merely the approval of a wiring device as safe for use in a home or the inspection and approval of elevators traveling hundreds of feet per minute, these agencies are constantly on the alert for new ways and means of making this technical world a safer one in which to live.

CHAPTER IX

PROBLEMS OF THE SUPPLIER—DEVELOPMENT

DEVELOPMENT NECESSARY TO CONTINUED SUCCESS

Any economic unit, engaged in production, to be successful must direct its efforts in three ways:

1. In producing a useful product or service in the best and cheapest way it knows how.
2. In improving this product or service, so that it meets consumer requirements better in each succeeding year.
3. In developing new products or services, the nature of which falls in line with the chosen sphere of activity, which will meet existing and new consumer demands.

These principles are fundamental to progress. In a changing world, no producer can stand still. Each is much in the same position as an individual who is crossing a swamp; if he stands still, he sinks lower and lower and is soon unable to move at all. The history of the collective progress of industrial companies of all sorts shows a surprising number which have fallen along the wayside because they have attempted to do the same thing over and over again in exactly the same way.[1] They have lacked vision in recognizing the value of improvements and the various opportunities offered by altering conditions of all kinds.[2] A far greater number of companies have failed

[1] Examples of failure of industrial companies due to failure to improve old products or develop new ones can be found in almost every industry. A manufacturer of elevators doing a large and profitable business failed to grasp the possibilities of improvement by means of higher operating speeds, automatic control, the adoption of floor leveling mechanisms, and better signaling systems, and consequently was pushed aside by its competitors.

A manufacturer of steam engines failed to recognize the growing demand for steam turbines and internal-combustion engines, and kept on building only steam engines in the face of an increasing demand for power-producing units of all kinds. In a period of business depression, this company discontinued business entirely.

A construction company, once highly prosperous, continued to use old methods and machinery in executing its various contracts, and as a result was put out of iness by more far-sighted and aggressive competitors.

[2] "Maine Manufacturing Company Starts Comeback with Complete Redesign 1," *Sales Management*, December 15, 1936, p. 1040.

from this cause, than because of the development of products of the wrong kind, or products which have been too advanced in type to meet the current market.

The producer, therefore, to be successful not only must invest in well-organized personnel and facilities required to conduct a current business, but also must carry on programs of improvement and development.[3]

REFERENCE

M. W. SMITH, "The Importance of Research and Development in Maintaining Technical Progress," *Electrical Engineering*, December, 1938, p. 484.

WHAT IS RESEARCH?[4]

The word "research" is a much-abused term, and often is incorrectly used. In its true sense, it applies only to work directed to the uncovering of *original ideas*. Testing materials or checking performance does not constitute research, no matter how valuable it may be in reaching or improving existing standards.

The distinction is usually made between "pure" and "applied" research. Pure research is pursued with an aim to discover new natural laws. This has been left by industry largely to educational institutions or societies and organizations most of which have been founded and maintained by endowment. Some pure research is undertaken and carried on by large business organizations, or a group of smaller organizations, as a contribution to scientific progress.

Applied technical research, on the other hand, is carried on by many companies,[5] both large and small, that maintain staffs and facilities for the purpose. Ideas created in the field of pure research are, of course, applied, but the central purpose of applied technical research is to develop ideas which may be put to use toward a practical end. Manufacturers of oil engines, for instance, may devote talents

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[3] "Olds Engineers 'Beat the Gun' to Driver Needs," Joseph Geschelin, *Automotive Industries*, April 10, 1937, p. 554.

[4] "Research is the reconnaissance party of industry, roving the unknown territory ahead independently, yet not without purpose, seeing for the first time things that all the following world will see a few years hence."—S. M. Kintner in "Exhaust Lines," *Power*, September, 1937, p. 505.

It is estimated that industrial and engineering research cost $180,000,000 in the United States in 1938, and that it employed 44,000 workers in 1700 laboratories.

[5] The activities of the research division of one large motor car company are divided as follows: 40 per cent consists of consulting engineering advice; 40 per cent product development; and 20 per cent basic science. The division also selects and trains engineers for the other divisions.—From "Research for Results," *American Machinist*, June 29, 1938, p. 550.

of this nature to a study of the materials going into the structure of the engine, and the ability of these materials to withstand wear, shock, and extreme temperatures, or to the vaporizing of oil and the various conditions under which combustion takes place to the best advantage.

Certain conditions must exist if either pure or applied research is to be carried on successfully. A marked degree of detachment from other company operations must exist, both to avoid interruption and interference, and also to avoid the stressing of immediate economic results. Research work, though of great commercial value in the long run, cannot be expected to produce immediate results of commercial value. Under such circumstances, research work, to be successful, must be pursued consistently over a period of years, irrespective of current fluctuations in business activity which characterize those conditions under which a production organization operates.

Any such technical department or organization requires careful business management, for the research engineer, engrossed in his work and even enchanted by it, may easily follow inviting sideroads which lead to no apparent useful end. Objectives must be established and obstacles identified, and from these a program of experimentation laid down and consistently followed. To accomplish this, in most well-organized research laboratories of importance, there is a chief of staff who is a man of broad vision, experience, and skill, and also a manager is employed who schedules and follows the work so that procedure is systematic.

No matter how well planned and administered technical research may be, often some of the most valuable results appear as accidental discoveries. This emphasizes that research work cannot be too closely supervised. Sometimes these discoveries are unexpected—yet distinct by-products of the work in hand, and have no relation to the immediate problem which is calling for a solution.[6]

Those best fitted to undertake technical research require not only extensive training, but also infinite patience and determination. An eye to commercial values also helps to keep the research engineer on the track, and enables him to see and recognize the possible usefulness of discoveries as they are made.

It will be obvious to the student that all kinds of technical research prove of benefit to society generally far beyond the benefit

[6] A London doctor, while conducting research work on gold compounds for arthritis treatment, accidentally discovered a method by which glass, china, and fabrics may be coated with a thin film of pure gold at small cost. Materials processed by this procedure are not readily distinguishable from those of solid

accruing to the individual company conducting it.[7] What is done in one field supplements, as well as stimulates, what is done in another. Industry is learning the value of cooperation among companies making different and also related products. Trade secrets acquired through research and experimentation are not so closely held as formerly, and individual companies are learning the value of a freer interchange of valued information. Fortunately, there is an increasing tendency to coordinate research to avoid unnecessary duplication, and for companies to consider more carefully the value of interrelated research in certain fields.[8] Much remains to be done in this direction, however, so that experiences and knowledge gained in one field are available to a greater degree to those in the same field or in other fields where it may prove valuable.

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HOW DO IDEAS ORIGINATE?

In retrospect, we are inclined to attach the origination or development of an important idea in the world of technical accomplishment to one man.[9] As a matter of fact, a number of minds have usually

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[7] For many years, "scrap iron" was worth almost nothing. When the useful life of products made of ferrous metals ended, they were commonly discarded and the metal in them considered worthless. With the development of the open-hearth furnace, through research, this so-called "scrap iron" could be used again, with the result that, in 1937, 28,500,000 tons of it were consumed which might otherwise have been discarded.

[8] In the development of the huge 40-passenger four-motored Douglas DC-4 landplane completed in 1938, five major airlines of the United States, in addition to the manufacturer, participated.

[9] "Discovery and invention do not spring full grown from the brains of men. The labor of a host of men, great laboratories, long, patient, scientific experiment build up the structure of knowledge, not stone by stone, but particle by particle. This adding of fact to fact some day brings forth a revolutionary discovery, an illuminating hypothesis, a great generalization, or a practical invention."—Herbert Hoover, p. vi, "Research, The Pathfinder of Science and Industry," T. A. Boyd D. Appleton-Century Company, Inc., New York, 1935.

been responsible for such ideas, and often these minds are separately engaged in the development of ideas which later prove to be of great value to society. Sometimes these ideas are announced almost simultaneously. One originator may desire to perfect his idea by proof and experimentation, which require time, while another announces his idea with perhaps less supporting evidence at the moment and hence receives credit from the populace. It is generally acknowledged that Alexander Bell invented the telephone. His patent was filed on February 14, 1878. Elisha Gray, outstanding electrical engineer and founder of the Western Electric Company, was engaged in developing similar ideas, and filed his patent papers only two hours after Bell filed his. A long battle in the courts ensued, and twelve years later, the patent was granted to Bell.

It seems most logical to conclude that ideas such as these emanate from the individual himself, but that they are based upon a vast field of information developed and made available by those who have gone before. Many individuals classed as original inventors did little to make the ideas attached to their names of practical value; this was left to those who came after to accomplish. Undeveloped ideas are in the minds of an unlimited number and are matters of everyday conversation, but the engineer and the laboratory are required to bring them into practical use. Neither James Watt nor Robert Fulton [10] was as famous for the original ideas which he conceived as for the fact that he developed his ideas and put them to practical ends.[11]

Reference

Paul Christiansen, "Ideas—Where Do They Come From?" *Machine Design*, May, 1938, p. 37.

ENGINEERING AND PRODUCT DEVELOPMENT

The engineer who designs, produces, and applies technical products is not engaged in research work in the correct sense of the word. His

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[10] There has been much controversy over Fulton's being given credit for the steamboat, since it is claimed by some that John Fitch, or others, were before Fulton in its invention. However, the origination of the steamboat idea and its first practical use are put still further in the past by F. O. L. Chorlton in his presidential address before the Manchester Association of Engineers. As reported in the *Steam Engineer* (London), he said, "Mention is made in documents from the Royal Archives in the Castle of Simancas in Castile, of a successful attempt to move a ship in the harbor of Barcelona in *1543*, by means of steam-driven paddle wheels. Details are not given, and as the experiment was frowned upon by the religious authorities, it was not pursued."—From "Exhaust Lines," *Power*, October, 1938, p. 73 (545).

[11] Thomas A. Edison has passed these words on to the coming generation of engineers: "The first thing is to find out everything everybody else knows about a subject and begin where they left off."

job is to devise ways and means of doing things in an economic manner which will meet the everyday requirements of a work-a-day world. His work certainly calls for experimentation and trial, but he follows basic laws and principles already largely established and puts them to use. Often he encounters problems where applied research and perhaps pure research are desirable or necessary, and he turns to the research engineer for assistance.

The engineer, engaged in engineering and product development, must first inform himself on what has already been done. He must "catch up" on the particular problem and the phase of the art or science that is involved. From there he must not only "keep up" with the advance of progress, but even get ahead of it, as one who contributes to its progress.

In developing products, the designer of new machinery, for instance, requires four lines of vision, directed largely either internally or externally. They may be summarized thus:

> *Materials.* He must know the characteristics of materials, their availability, and cost. For this, his practical source of information is through those in his organization who deal with the supplier. With the rapid development of new materials, such as alloys [12] and plastics,[13] an unusual degree of alertness is necessary.[14]
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> *Processes.* He must understand existing and potential manufacturing facilities and processes within his own factory, because his design, if successful, must be such as to permit simple and economic manufacture.[15]

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[12] The new streamlined Twentieth Century Limited, put in service (June, 1938) by the New York Central Railroad, includes forgings of molybdenum steel for pistons and side rods, weighing about one-half as much as those ordinarily employed.

[13] At present writing, developments on the way in the field of new plastics bid fair to revolutionize the design of many products. Both new materials and methods of molding and fabricating them indicate this field to be one with great resources.

[14] We may, at times, compare progress in engineering developments 100 years ago unfairly with that of today, for we must consider that the engineer of 1839 had about as many materials to work with as he had fingers, whereas today the engineer has not only an enormous variety of materials, but also a thorough knowledge of them. *Machine Design's* directory of materials used in the design of machinery is an excellent illustration of what an engineer has at his disposal today. See *Machine Design,* October, 1938, p. 14D.

[15] The engineer must understand, for instance, the limits within which surfaces can be machined or ground—the merits and limitations of cast iron, cast steel or structural welded framework or housings—and where die castings can advantageously be employed.

It is interesting to note that already several manufacturing plants have installed certain machines in air-conditioned compartments in order to preserve a constant condition of humidity and temperature where extremely accurate machining is to be done.

Market. He must understand not only what customers desire now, but also what improvements are most sought after. In addition, he must know what characteristics are desired in the interests of economical distribution.

Competition. He must know what competitors offer and what success or handicaps are attributed to their designs.

Progress in the redesign of technical products comes from such sources as those listed below, which give direction to the efforts of the development engineer:

1. Complaints and criticisms of existing current designs, which uncover features that have failed or proved not fully adequate.
2. Additional duties which the product of existing design might perform, and which might be incorporated in a modified design.
3. Changes that would permit more economical manufacture.
4. Substitution of more suitable and perhaps less expensive materials.[16]
5. Alterations which will create greater customer acceptance.
6. Changes which increase the capacity of the product to yield a larger output.[17]
7. Changes which will facilitate more economical and efficient distribution, in all its phases.

The attitude of the development engineer, in the interests of progress, must of necessity be most critical of existing designs for products. He can never afford to be satisfied. Those who create something improved and new are often partial to the child of their brain, and a proper balance is necessary, on the part of the designer, between the extremes of pride and confidence, and complete dissatisfaction.

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[16] Nylon is an example of a better and cheaper substitute for an old material. Nylon is the name given a plastic developed by du Pont, made of coal, water, and air, which is destined to replace silk and rayon in many uses. It will knit into sheer elastic stockings and has greater elasticity than any of the natural fibers. Extremely fine filaments can be fashioned, which are as strong as steel of an equal diameter, making Nylon valuable both for sheer clothing and for tougher articles, such as fishing lines and racquet strings. An $8,000,000 mill is being constructed to begin mass production of Nylon in 1941.—"This Synthetic Age," *Reader's Digest*, February, 1939, p. 81.

[17] A middle-western manufacturer of screw machines has devised a simple attachment to its multiple screw machine. This attachment involves an auxiliary spindle mounted opposite the cutting-off spindle and driven in the same direction and at the same speed. The work is grasped by a chuck before it is severed. Before, during, and after the cut-off, when additional operations are performed, the work is thus supported. Better work and a more rapid operation of the cut-off tool are obtained.

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WHEN SHOULD ENGINEERING DEVELOPMENT TAKE PLACE?

Many a manufacturer has awakened to the reality that current designs have become obsolete. Others have brought out new products to find them obsolete shortly after they have been placed in production and offered for sale. Engineering developments require time for accomplishment, and progress comes slowly. Large investments in capital for manufacturing equipment and facilities are necessary, as well as for personnel to carry on the work. Even all these expenses may be small, however, compared with the losses which finally come to any organization which does not keep its products abreast with its competitors and the market.

Consequently, engineering development is necessarily carried on continuously.[18] In times when business conditions are depressed, engineering development is most desirable, for not only will the announcement and availability of new products assist in hastening recovery, but also at such times plant facilities are less busy than usual in regular production work and hence development work has a freer road to progress. Each year more manufacturers of technical products are adopting a policy of supporting and stressing engineering development work in slack times.[19]

STAGES IN PRODUCT DEVELOPMENT

Today, surrounded by technical products which find hearty acceptance and extensive demand, we easily lose sight of the long course of

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[18] Reference: "New-Products Programs," G. F. Nordenholt, *Product Engineering*, March, 1938, p. 103.

[19] This point emphasizes the wisdom of ample working capital for the industrial enterprise, a subject elsewhere mentioned, so that such work in periods of depressed business can be pursued without financial embarrassment.

The steel industry spent over $10,000,000 for product research in 1937. In 1938, its production dropped 60 per cent on account of economic conditic and observers expected a similar curtailment of research expenditures. However, contrary to past practice in the industry, a long-term viewpoint of research was adopted, and the 1938 expenditures for research were approximately $9,500,000, or almost the same as in 1937.—*Inter-Industry Selling*, September, 1938, p. 2.

development that has been necessary before present-day perfection was attained. The steps which the development of such products follows are usually these:

Invention and experimentation, pursued in laboratories.

Practical trial of some form of completed unit, naturally limited to conditions surrounding single installation.

Small-quantity production and field trial, often repeated.

Introduction to the user, in which the apparatus is offered for public sale.

Expansion and competition, quantity production and competitive activity.

Acceptance and replacement; the product finds acceptance, and progress causes obsolescence.

Finding new uses; the ingenuity of the engineer devises new advantages and greater means of utility.

Let us consider these various stages in connection with the household mechanical refrigerator, which during relatively few years has become so popular and appealing to the eye.[20]

Refrigerators for manufacturing ice and furnishing cold storage had been in use several decades before the domestic type of machine was originated. Certain limitations, such as size, weight, risk due to refrigerating fluids such as ammonia, disposal of heat, noise, initial cost, and cost of operation, were obstacles preventing its acceptance for domestic service.

Research engineers became interested in the problem, particularly at the instigation of industrial leaders who saw a large market for a device of this sort. Experimental models were built, forms of refrigerants investigated, methods of cooling tried, and extended laboratory tests carried on. In time, several different designs were developed and placed in practical service [21] in a few homes. A host of difficulties

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[20] Similar examples could be chosen from almost any field of design covering equipment for the office, store, service shop, factory, railroad, farm, etc. Today, designing engineers cannot rely upon their own judgment and taste in determining what design features appeal to the eye. Most companies employ industrial artists or "stylists," or, for products purchased largely by women, experts in the particular field.

[21] No matter how carefully a product is tested in the laboratory, it is usually found to include weaknesses which develop only from practical test when used under the large variety of conditions encountered in the practical service for which it is intended. It is impossible for the laboratory technician, no matter how skilled, to foresee or duplicate every possible condition to be met. Many such factors have to do with the treatment the apparatus receives in the hands of human beings, or shall we say the lack of it?

and obstacles, many of which were related to features of convenience and utility, developed[22] under conditions of actual service. Further design work and laboratory tests were required, and further field tests.

From this step, models were adopted as standard, and production facilities were arranged. For the first time, the domestic mechanical refrigerator was available for sale to the public.

From this point, expansion in volume proceeded rapidly; details were perfected and the cost reduced. The pioneers, who first saw great commercial possibilities in the field, were faced with competitors who were entering the refrigeration business. Increased competition stimulated further development in design and manufacture.

In time, this product received general public acceptance, and, as further improvements were rapidly made, original users saw the advantages of such a product and discarded old models for the new.

Finally, new uses for the domestic mechanical refrigerators were introduced. All kinds of desserts and ices could be prepared by such machines; by modifications in form, water coolers were developed; and more recently further modification in structure produced equipment for house cooling.

With this particular article, the designing engineer encountered problems in customer acceptance dealing with taste, style, and convenience that were of extreme importance, for here a complicated machine became closely associated with the daily life of the woman in her home. Form and color, which had little to do with success in operation, became prime factors. The less the product looked like a machine, the better. What interested the purchaser most was that the machine should become a silent, convenient, and attractive article of kitchen furnishing.

One noticeable effect which the acceptance of technical products in all phases of life has had upon the development engineer is that under changing conditions he must of necessity see for himself, outside the limits of the laboratory, those conditions under which such products are bought and used.

Continually, new mechanical and electrical appliances are being developed and introduced. The history of activity for each appliance follows very closely the course of progress which has been outlined.

author had in his home, in 1924, a water-cooled electrically operated domestic refrigerator. It lasted about six months. It was very noisy in operation, caused radio interference, which at that time might hardly be considered an objection owing to the limited use of receiving sets, and also failed since the city water contained enough acid to destroy certain parts essential to the cooling of the compressor.

The electric shaver[23] serves as an interesting example, which, at present writing, has proceeded to the stage where it is being introduced to the user.

PATENT ACTIVITIES

Our government, together with the governments of other leading countries, recognizes the advantages of stimulating invention, by protecting and thus rewarding those who develop new ideas which can be put to practical use. Through being granted patent rights, the inventor can, under certain conditions, possess a monopoly for a specified period of time in the manufacture of the patented article, and permit others to do so only upon the payment to him of royalties for this privilege.

Many of those who develop new ideas subject to patent control are now employed by various kinds of manufacturing and commercial organizations. Since such organizations provide the individual with facilities for research and experimentation, and pay the inventor or discoverer for his work, it is customary that the ideas which he develops should become the property of the company employing him. Special arrangements in this regard, however, including compensation for unusual inventive efforts, are often made between employee and employer. Most patents are worth little unless rights can be obtained under other patents covering the same or closely related fields, for patents in our days relate largely to particular features of design and operation. For instance, a hundred or more patents may be granted upon the detailed features of one machine, and hence an individual patent may be of little use in itself.

Patent activities have become complicated and highly specialized, and it is customary for most companies to engage patent counsel, unless their operations are extensive enough to support a group of patent attorneys of their own. Patents often are contested in the courts, and skill and resources are required in supporting them. The protection afforded by a patent may, therefore, depend upon those who hold the patent, to a great degree, and to their ability to defend it.

Common policy in the granting of licenses under patents has undergone change. Products which are not only new but also involve radically new principles may be difficult and expensive to exploit by only one supplier, because the supplier has the problem of selling a radically new idea in addition to a particular product. Most com-

in the number of electric shavers has pursued the following course: 1933, 43,234; 1934, 76,616; 1935, 419,933; 1936, 1,222,971; 1937, a retail value of more than 25 million dollars.

panies which are fortunate enough to be faced with a situation of this kind choose to license under royalty one or more of their competitors, with the understanding that they, too, will aggressively exploit the new product. Thus progress is made cooperatively to the interests of several suppliers and of the purchasing public.

The procedure for securing a patent is an interesting but complex one. Under the laws of this country, patentable inventions must relate to the following; inventions and discoveries not so concerned are not patentable: [24]

1. A machine.
2. An art (a new process or method that is useful).
3. A new and useful composition of matter.
4. A manufacture.
5. A new design for some article of manufacture.
6. An improvement in an art, machine, composition of matter, or article which already exists.[25]
7. A new variety of plant, other than tuber-propagated plants, capable of asexual reproduction.

Except during the Civil War and periods of great depression, the rate of patent granting has constantly increased until today it is not unusual for 120 patents to be granted in one day. Over 2,000,000 have been granted in the past 100 years. With such complexity, it becomes advisable that anyone seeking a patent first hire a patent attorney who is certified by the United States Patent Office in Washington. After this, the invention or discovery must be fully disclosed to the attorney, with the aid of sketches and models if possible. The patent attorney decides whether it is necessary to conduct a preliminary "search" to find whether there are any existing conflicting patents or publications.

The next procedure is to draw up the application for the patent. The patent attorney draws up these documents; they consist of:

1. A petition to the Commissioner of Patents.
2. Claims defining the coverage of the inventor's monopoly.
3. A complete written description of the invention.
4. If the invention is suitable to illustrations, drawings in India ink on Bristol board.
5. An oath.

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[24] Reference: "Manufacture of Parts May be Valid Trade Secret," George V. Woodling, *Machine Design*, September, 1938, p. 35.

[25] Reference: "Change in 'Function' May Constitute Invention," George V. Woodling, *Machine Design*, June, 1938, p. 35.

The one applying for the patent signs the oath, petition, and specification, and sends the application documents along with a filing fee to the Commissioner of Patents in Washington. If the application is found complete in Washington, a *filing certificate* is sent the inventor or his attorney. This allows him to mark any manufactures of his invention with "Patent Pending" or "Patent Applied For."

Highly trained technical and legal experts in the Patent Office examine the application carefully, and it is compared with prior patents if an analogy is possible. After it has been determined that an invention or discovery is patentable, the inventor is granted a patent giving him a monopoly over his invention for a period of seventeen years from date of granting, during which time others are excluded from making, using, or selling the inventor's invention. At the end of seventeen years, the invention always becomes public property.

The rights granted to a patentee may be transferred to any other person by the patentee. Any such instrument in writing that amounts to any assignment, grant, lien, mortgage, incumbrance, or license, or that affects the title of the patent or patent application to which it relates, should be recorded in the Patent Office.

Trademarks by which products are identified are comparable in some ways to patents, but unless the products are involved in interstate commerce, trademarks may be registered only with the states. When the products are in interstate commerce, trademarks may be registered with the United States Patent Office.

CHAPTER X

PROBLEMS OF THE SUPPLIER—PRODUCTION

INTRODUCTION

No branch of industrial activity depends so generally upon the application of economic principles as does production. In considering the problems of the supplier in the field of production, our purpose is not to cover the detailed methods of economic production, which engages the specific attention of the student specializing upon the subject of industrial management, but rather we shall attempt to review the subject of production for the purpose of identifying, illustrating, and establishing the economic principles involved.

We find that the actual production of utilities takes several forms:

> That of extracting what we consider of value in the form of substances or forces from the surface of the earth, as lumber, minerals, petroleum, gas, soy beans, rubber; or from the air, as nitrogen.
>
> The erecting of a great variety of permanently located structures, as dams, bridges, or buildings.
>
> The processing or fabrication of products, which we call manufacture, as steel, paper, automobiles, machinery, clothes, and food products.
>
> The creation of various forms of service, and making them readily available to the user, as transportation, electricity, or gas.

In actually setting up the facilities for production,[1] and in the use of these facilities as production proceeds, we again find the necessity of following physical principles involved in technical procedures, as well as those principles which concern social order. However, to be successful, each step we take must be based upon decisions of an economic nature, for the final object of production is to fill a want adequately in the most economical way. Successful production is accomplished, therefore, only through an almost infinite number of selections and decisions based upon the laws of economics.

In a study of economic procedure, as related to production, we find our attention focused upon:

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[1] Reference: "Engineering the New Plant," Thomas W. Hopper, *Factory Management and Maintenance*, April, 1938, p. B60.

The selection of a location at which production is to proceed.

The selection, arrangement, and maintenance of facilities and equipment required for production.

The organizing of the forces of capital, management, and labor.

The supervision, control, and compensation of the organization which has been created, as economic production proceeds.

Since manufacture plays so important a part in the field of production, and in itself depends so largely upon utilities created through such activities as construction, mining, and the furnishing of power and transportation, we will devote our attention, largely, to the more important considerations in the economics of physical production.

The objective of management in the manufacturing plant is not just to produce goods, but to produce them within the required *quality* standards, within the necessary *time* limits, at the cheapest possible *cost*, and in the *quantities* demanded by the market. The engineer too often concerns himself with the problems of quality and quantity, and neglects to consider that, if the things he is designing cannot be produced to satisfy the requirements of time and cost, his efforts are in vain.

IN THE STUDY OF CHAPTERS X AND XI

"500 Quick Ways to Profit," *Factory Management and Maintenance*, November, 1938. The student in studying production will find this article of particular interest, since it demonstrates actual savings effected in all functions of production. The article is conveniently divided into eight headings: (1) materials handling, layout and motion economy, beginning page 59; (2) power and light, p. 65; (3) mechanical power drives, p. 73; (4) heating, ventilation, and air conditioning, p. 79; (5) buildings and services, p. 99; (6) production planning and control, p. 105; (7) public and employee relations, p. 111; and (8) production methods and materials, p. 117.

'rogress Edition" of *Mill and Factory*, June, 1938, p. 75. A good of information in studying industry and production.

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F. ZAPPONE, "How We Organized a Welding Department," *Factory Management and Maintenance*, February, 1939, p. 62.

OF PLANT

From the standpoint of economic considerations, the selection of the site for a plant for manufacturing presents one of the most difficult and involved problems that management must solve. Just as in a design where we wish to accomplish our purpose by the most economical combination of parts and processes, so with plant location must we weigh every factor affecting cost of operations, together with less tangi-

ble factors, and then locate our plant at that place where the sum of all economic advantages is greatest. Such considerations require a complete study of the economies of producing, distributing, and overhead expenses for each suggested location. Two general points should be kept in mind during the selecting process. The first is the importance of a good manufacturing location from the viewpoint of changing conditions in the requisites of production and the demand for products to be furnished—both of which may be modified by the introduction or elimination of competition; the second is that, once a location is selected, those cost factors dependent upon location will largely pass out of the control of management and become fixed.

The various important factors that affect economic plant location may be summarized in the following:

Factors in determining the selection of a regional geographic location:
- Cost and availability of raw, semi-finished, and finished materials required in production.
- Cost and quality of labor.
- Cost of services, such as power and transportation.
- Governmental laws.
- The relation to other of the producer's activities.
- The location of the market for that which is produced.
- Availability of cheap capital.

Factors in determining the selection of an immediate location:
- Special inducements of local interests.
- Rents and property values.
- Hazards.
- Taxes.
- Waste disposal.

It will be noted that, in selecting the location of a plant, consideration must be given not only to conditions which exist at the time the selection is made, but also to probable changes which may occur in these conditions, judging from existing trends and anticipating the probable course of events. Foresight in selecting a plant location has often been the ruling factor in the success of the plant and the enterprise, because such a decision determines, to a large extent, the cost of doing business.

No one of the factors named may be the sole factor of determination. In arriving at an ultimate decision, all factors must be considered, and after each has been determined, the problem arises of evaluating their relative importance, both present and future. As we shall see, judgment factors, as well as fact information, enter into the final decision.

The *cost and availability of materials required* may entirely limit the selection to one or a few locations, as would be true in locating an oil well, mining operation, or sawmill. Having tentatively selected such location possibilities, one then proceeds to other factors involved.

The *cost of labor* has become of increasing importance as a matter to be considered in plant location, since it forms so large an item in cost of production, and failure or irregularity in obtaining labor can so severely affect the success of any enterprise.[2] We continually find instances where labor supply is a major matter of importance in establishing a plant engaged in manufacturing processes. Long ago, textile plants would have been prevalent in the South had an efficient supply of labor existed there. Many companies engaged in printing books and periodicals have moved from large cities to smaller outlying towns, because of a more stable and efficient supply of labor; newspaper plants, however, cannot do so, because their product has to be in the hands of the purchaser immediately upon completion.

The *cost of services*, such as power, gas, or transportation, varies in importance with the kind of product furnished. Cheap electric power may be a leading factor, as for many chemical and metallurgical processes. In producing steel, an abundance of heat is required for open-hearth and reheating furnaces, and so the availability of natural gas did much to encourage the growth of steel manufacture in the Pittsburgh district.

Some years ago, a manufacturer established a plant in St. Louis, Missouri, for the manufacture of spun concrete lighting poles. A large contract for these had been obtained for local delivery. After this order was completed, difficulty was encountered in meeting competition over other parts of the United States owing to the cost of transportation, and manufacture was discontinued. Transportation costs are a vital point in factory location, applying both to incoming materials and those produced. The manufacturer of heavy and bulky apparatus, for the most part, finds it necessary to establish plants in localities where the market can be met with the minimum transportation costs.

[2] A prominent automobile manufacturer recently had his production tied up by a strike in the plant of his tire manufacturer. Although cars were coming off his assembly line as usual, he was not able to secure tires to put on them, and as a result his assembly plants were temporarily closed up. To prevent a recurrence of this "bottle neck," the automobile builder constructed his own tire manufacturing plant in a district noted for harmonious relations between employer and employee, and will now build a sufficiently large proportion of his tires there to insure continuous operation of his assembly lines. In this case, the freedom from labor troubles was a determining factor in the location of this tire plant.

Laws made by our various governmental authorities influence the desirability of plant location. Such laws relate not only to taxation, but also to such matters as factory inspection, labor rates and relations, working hours, child labor, incorporation costs, compensation insurance, and employee security. Mississippi has passed laws, for instance, making possible complete public financing of industries, provided that raw materials from the state are utilized.

The *location of the market* is often predominantly a factor in choice of factory site, and leads all producers of commodities to locate plants centrally in respect to the market area to be served.

It has become quite common for states, counties, and cities to provide *special inducements* to manufacturers to establish plants within their jurisdiction. Taxes may be eliminated, free plant sites made available, and other inducements offered in order to attract industries which employ labor and add to business activity.

Rents and property values differ greatly in various immediate locations—likewise the cost of buildings.

Hazards due to fire, earthquake, etc., and the disposal of waste materials and the discomfort from noise, are all factors which are of distinct economic significance. Most municipalities have zoning laws which forbid erecting factories within certain districts. The emission of heavy smoke, gaseous fumes, or an abundance of fine dust resulting from manufacturing processes may affect public health adversely, and cause complaints and costly lawsuits. In many of our states, plants were originally established on the banks of rivers to obtain a supply of water and get the advantage of transportation by water. Waste materials and sewage from these plants usually went directly into the rivers, resulting in their pollution, a practice which is being forbidden to a great extent through legislation and is being eliminated by increased installation of sewage-disposal plants.

Increased *tax rates* have influenced the location of plants greatly and, in some instances, have caused changes in plant location to other districts where such rates are lower.

As a matter of fact, most new plants are established by existing companies, and here other matters of practical consideration enter into the question of selecting a plant site. An existing enterprise may have one or more plants in different localities, and is faced with the problem of expansion, which leads to the selection of an additional plant site. Therefore, attention must be given to all the factors that have been named, but also the selection will be made with reference to existing plants. For instance, a manufacturer of equipment used in all classes of buildings, such as ventilating apparatus, may have two

plants located in the northeastern part of this country—one in New England and another in the north central states. In an endeavor to serve the market better in states west of the Rocky Mountains, and particularly the Pacific coast states, it becomes desirable to establish a manufacturing location in that region. Let us say they select a manufacturing site at Emeryville, California, which is found to meet the most advantageous conditions as nearly as possible. A decision must also be reached as to what operations will be conducted at that point, whether all classes of product will be completely built there, or whether only certain products which must be furnished on short delivery and built according to individual customer needs.

Furthermore, there may be economic advantage in building certain standardized parts of the equipment in one or both of the eastern plants, thereby gaining the low-cost advantages incidental to quantity manufacture, and carrying a stock of these at the Pacific coast plant which can be used in completing equipment there. Many companies have thus found it desirable to establish what is termed "assembly plants," or plants which combine, in the manufacture of the finished product, parts made elsewhere and parts, usually of a special nature, made locally.

Those companies which build a variety of products usually endeavor to select manufacturing locations suited both to meeting the local market and to making the individual product—as must a manufacturer of equipment and supplies, for instance. A manufacturer of a variety of machines used for canning and preserving, handling fresh and dried fruits, and similar equipment, has established plants at several localities. One plant, for instance, at Portland, Oregon, makes apparatus for grading and packing fresh apples and other fruits raised in that section of the country, while other plants are located in Southern California and Florida manufacturing machines for washing, grading, artificially coloring, and packing citrus fruits. Since this same company makes irrigation pumps, one point of manufacture is in central California to serve the extensive needs west of the Rocky Mountains.

In view of the constant change in the location of markets, and to a lesser extent in natural resources, power supply, labor supply, transportation facilities, and tax burdens, many manufacturers are always faced with re-evaluation of their factory locations, and must consider the advisability of expanding one factory location and reducing the size and activity of another.

It will be seen that no formula can be contrived which will determine plant location. The decision must be reached after an assembly of all cost factors of the character described, a study of trends,

the application of experienced judgment. A few examples will illustrate recent decisions regarding plant location and expansion.

A manufacturer of coal stokers, used for house heating and in buildings and smaller factories, developed his business in the extreme Northwest. As business grew, he found the location desirable in all major respects, except for the distance from the main sources of raw materials and from the large markets. The manufacturer decided to acquire a manufacturing location in the eastern part of the country, and, upon the basis of those economic factors we have been discussing, selected a large city in Ohio. The selection proved to be sound, and before many years this developed into a much larger manufacturing location than the western one. The greatest demand for coal stokers exists where temperature conditions are severe, coal is cheap, and competition from other forms of heating less pronounced.

A manufacturer of small electric motors for driving appliances used in the home, office, and shop established its factory many years ago in New England, since this company had several scattered plants making various products, and it so happened, at the time of establishing the small motor factory, that one of the company's New England plants was vacant and available. The decision to manufacture small motors at this point was based upon these facts at that time:

Favorable

The availability of an existing vacant plant, which, with minor modification, could be adapted for the purpose.

A good labor market, consisting of tool and die makers, machine tool operators, and assemblers.

The availability of the more expensive finished materials, such as brass and copper.

Cheap and reliable power.

Reasonably good transportation facilities.

A market for the manufactured product in the general region of the plant.

Unfavorable

Distance from the main supplying points of steel and iron.

Distance from the large market centers for standardized small motors used by such companies as manufacture electrically operated washing machines and vacuum cleaners, which were located, principally, in the Middle West.

After several years, a complete study of plant location was made in relation to this product. In the meantime, the market center had moved farther west, and was found to be within the region covered by the states of Ohio and Indiana. Also, other uses appeared for the

existing manufacturing space, and much of the productive equipment, of the New England plant. From a careful survey, and a detailed study of available factory sites which, owing to poor business conditions, were many, it was decided to purchase an existing vacant plant in a medium-sized Ohio town, and equip this in a modern way, discontinuing manufacture in New England. Favorable conditions of manufacture were thus met, such as:

Closeness to the center of countrywide demand for the finished product.

Excellent transportation facilities in all directions, by rail and truck.

A suitable and low-priced site and building layout.

Good labor market: almost entirely native workers, many of whom lived in the country within easy access to the plant.

Cheap and reliable power, and low-cost fuel for heating.

Favorable tax conditions.

Closeness to a supply of raw and semi-finished materials.

A manufacturer of water supply pumps, located in Southern California, built up an extensive business on the Pacific coast in the irrigation fields. As this company developed, it found an expanding market for its products for irrigation work in the entire southern part of the United States, as well as foreign countries to the south. Moreover, an expanding demand developed over the entire country for these water pumps by smaller municipalities, and by many types of industries such as paper mills, petroleum refineries, chemical plants, laundries, and dairies. Distributors and sales supervisors were established over the entire country. As business grew nationally, it became increasingly difficult to meet the prompt demands of customers who required a wide variety of pump sizes to meet various operating conditions. A manufacturing location east of the Rocky Mountains was considered, and it was decided to locate a plant somewhere in the central part of the country, this decision being based upon those economic factors which we have outlined. A vacant plant was located in Missouri, and its choice has proved economically sound.

Industrial manufacture is continually on the move, and during recent years this tendency has been accelerated.[3] The very factors which we have named as of consequence in selecting a factory location are, in most instances, undergoing continual change, and are the motivating forces in industrial migration. Not only is management becoming more alert to a careful appraisal of the various factors regarding location, which influence successful production, but it is recognizing

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[3] Reference: "Paper Goes South," D. H. Killeffer, *Industrial & Engineering* y, October, 1938, p. 1110.

that there are limitations to the economic size of an individual plant. Some industrial leaders have been giving increasing thought to decentralization [4] of manufacture by developing a plan of establishing small plants, many of them in rural communities,[5] where workers can enjoy greater security through part-time farming.

CHARLES P. WOOD, "Where to Locate the Plant," *Factory Management and Maintenance,* April, 1937, p. 46.

GEORGE C. SMITH, "Where Shall We Build," *Factory Management and Maintenance,* April, 1938, p. B39.

"Industry on the Move," *Business Week,* February 27, 1937, p. 43.

THE FACTORY SITE, BUILDINGS, AND FURNISHINGS

Many times, those who find it necessary to establish a new manufacturing site and buildings can choose between the alternatives of purchasing an existing plant or erecting one. In purchasing an existing plant, although the initial cost is usually tempting on account of the low outlay, additional costs occur, owing usually to the necessity of repairs and changes. These are commonly underestimated, and almost always production costs are higher in an old plant than in a modern one which is designed and built to meet the exact requirements of the purchaser. The most common causes for this are lack of ade-

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[4] Reference: "Decentralization of Industry," W. J. Cameron, *Mechanical Engineering,* July, 1937, p. 483.

[5] The advantages of small plants in rural communities are well portrayed in the following excerpt from the article "The Big Idea Behind Those Small Plants of Ford's," Arthur Van Vlissingen, *Factory Management and Maintenance,* April, 1938, p. 46:

> "Taking a few operations away from the large plants and putting them into small plants does not mean that mass production and centralization were mistakes in the first place," Mr. Ford likes to point out. "It simply means that, having learned certain things in centralized mass production that could not have been learned otherwise, we can now apply them in small plants. Decentralization is not a retreat or a confession of error, but an extension of the fruits of experience.
>
> "The small plant in a village or in the country makes for better working conditions, because it permits a more natural life. This, of course, is primarily due to the village or country itself. The life of an American village is a pretty fine thing. What the small industry can do is to make it possible for people to continue to enjoy the wholesome life of the country and at the same time enjoy a city income.
>
> "Removing industry to the country for the purpose of paying lower wages is not decentralization. It is the lack of income that drives people from the country to the city. A city income in country surroundings is easily possible—and that is what our small plants are intended, for one thing, to demonstrate."

Reference: "Some Advantages of a Rural Community from the Personal Relations Standpoint," R. C. Taft, *Iron Age,* August 19, 1937, p. 41.

quate and modern floors, light and power distribution systems, and facilities for heating and ventilating and the handling of materials. The choice between the purchase of an existing plant and the erection of a new one is based upon economic factors, many of which can be established in a reasonably definite way.

In choosing a factory site and determining the physical characteristics of the factory, we encounter a variety of economic problems, governed by established conditions concerning the product to be made, the processes involved, and those natural or existing conditions due to the immediate and general location.

So far as the site itself is concerned, these factors are of major importance:

> *Initial cost of the land,* which must include sufficient space for the necessary buildings, outside storage space if required, parking facilities, and land required for future expansion.[6]
>
> *Suitability of the location,* with regard to such matters as transportation, waste disposal, water supply, the availability of power and gas supply, proximity to homes of employees, and also the size and nature of the buildings to be erected.
>
> *Nature of land,* with regard to the cost of foundations, driveways, and non-existence of serious hazards from flood and other destructive agencies.
>
> *Restrictions* imposed by local governments.
>
> *Cost of taxes.*

So far as the factory structure itself is concerned, what course of economic reasoning must be pursued? Should *one large building* be erected, or *several smaller ones?* Waste floor space is more likely to occur where several buildings are erected, and these are more costly to heat. Sometimes, however, the hazards involved in certain operations justify a detached structure, as for a metal foundry. Or again, such pursuits as testing, research, or proving may be carried on more successfully in buildings set apart from production.

Next, a selection must be made of the *type* of building to be erected, which depends upon cost factors and their importance in comparison

[6] One large plant of a "heavy industry" was built in a valley because the land had been given to the founder as an inducement to bring his enterprise to that location. The company prospered with the passage of the years, and continually ...aded until it soon occupied every available square foot of ground in the ... Further expansion of necessity took the form of "outside" plants which ...cated in places distant from the parent plant. This introduced many complexities not found in a single-plant enterprise.

with the suitability [7] of the building for the product and processes involved. It must be decided whether to erect a single-story or multistory building.[8] In general, we can compare the advantages and disadvantages of these two types of structures somewhat as follows:

> The single-story building is advantageous where land is comparatively cheap, where taxes are low, and where the product can best be manufactured in "straight-line" production. In favor of this type of building is its superior natural lighting, ease of plant transportation, and greater effective floor area.
>
> On the other hand, where land is expensive and space limited, the multi-story type of building comes into its own. The lower cost of roof and foundations as calculated per square foot of floor space is also an advantage. The processes of manufacture of such products as flour and cement practically dictate a multi-story construction, since gravity conveyor systems are advantageous. Often, too, the multi-story idea provides for the expansion of an industry located in a crowded or congested district, where expansion on the ground-floor level only would be impossible.

Likewise, a choice of the types of construction used in single-story or multi-story factory buildings is necessary. These are:

> *Structural steel.* This type of construction permits heavy floor loads, long spans, and tall buildings.
>
> *Mill construction.* This type is made up of brick walls with timber framing, and is low in first cost.
>
> *Reinforced concrete.* This type of building gives great strength and permanency, without excessive first cost or high maintenance and depreciation. Its chief disadvantage lies in the reduction of useful floor space caused by the heavy beams and columns that are necessary in the construction of the building.

Forms of heating, lighting, ventilation, and even cooling, lead us into considerations which include established facts and also judgment

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[7] It is well to point out here that, even though the factory building comes into actual being before the layout of production facilities and processes, it is not designed in a similar order. The next and logical step after site selection is to develop fully the productive layout as intended. Then, and then only, should the factory building be designed to house this layout best.

[8] A prominent machine tool builder, located in New England, is established in an old multi-story plant near the center of an important city. The management recently purchased an attractive site in the outskirts of the city and is creating a large one-story plant, with two-story office building, power house, and garage. Ten years ago the largest machine required weighed only some 10,000 pounds, but today machines weighing as much as 80,000 pounds are necessary. The latter can now be well provided for, in the new single-story factory layout, and mar other advantages will be obtained from the point of production and benefit

factors. Scientific investigation is continually providing us with increasingly definite information, for instance, on the relation between conditioned air and the health of employees, the effect of better illumination in the elimination of errors and waste, and the result of color schemes[9] upon the tempo and enthusiasm of the workers. Thus, there are being established an increasing number of economic factors which formerly were not recognized as such. Architectural beauty in plant design carries with it an economic advantage through its psychological effect upon customers and employees, alike.

Flexibility in factory construction from the viewpoint of a change in the nature of the product or process may involve interesting economic problems which rest largely upon judgment factors. Years ago, a manufacturer erected a multi-story factory, in a middle-western city, for making electric lamp bulbs. It was at a time when automatic machinery for this purpose had not been perfected but was the subject of extensive research and development.

Shortly after this factory was completed, the perfection of automatic machinery reached a point where it became practical and generally adopted by lamp-bulb manufacturers. The plant which had been erected was found unnecessary, because ample space existed in other plants of the company for making, by automatic machine, many times the number of lamps required to meet market demands. The new plant, which was of light construction, lay idle for years, since it was unsuited for many classes of manufacture requiring heavy production machinery.

ALBERT S. LOW, "What's What in Plant Design," *Factory Management and Maintenance,* April, 1937, p. 56.

A. KINGSLEY FERGUSON, "Modern Trends in Factory Building," *Mill and Factory,* February, 1939, p. 51.

MORITZ KAHN, "What Type of Plant to Build," *Factory Management and Main-e,* April, 1937, p. 51.

FOR PRODUCTION

In the discussion of financing an enterprise, we referred to the necessity of capital, a large share of which is required for production facilities, when considering manufacture or the furnishing of various forms of service. It is quite necessary in giving thought to a productive layout that we fix our minds upon the value and nature of capital.

Supposing that one had $10,000 in cash, there are an infinite number of ways in which it could be invested or spent—or it could be

[9] Reference: "Color Increases Plant Efficiency," *Steel,* August 15, 1938, p. 61.

deposited in the bank and a small interest rate obtained. In the form of currency, it is distinctly liquid. If, on the other hand, we purchase a plot of land and erect and equip a factory for the purpose of manufacturing a certain product, the capital no longer is liquid, but depends for the maintenance of its value upon its ability, thus invested, to produce a profit. When it ceases to produce a profit, thus invested, its value starts to shrink, and if this continues, the whole or a large share of the investment is lost.

Assuming productive facilities in the hands of an enterprise possessing an efficient distributing system to an existing and expanding market, the value and stability of the enterprise's investment in productive facilities depend upon:

The suitability of the productive layout for the purpose intended.
The manner in which the productive layout is operated.
The continuing advantage of the location of the productive layout.
An adequate method of depreciating the value of both plant and equipment.

Frequently, in business today, we find some weaknesses in such factors as we have mentioned which are overcome by particular skill in others. For instance, we see old plants, often poorly equipped, that are so well managed that they can continue to operate against the competition offered by modern productive layouts, which are poorly managed; or, again, we see plants, poorly located from such viewpoints as the location of raw materials or of the market, that continue to do well owing to extremely clever management. The value of the investment, therefore, depends to a large degree upon management, for from management spring factors of weakness and strength.

When we consider actual conditions in business, we find that a large majority of new plants are erected by enterprises which have been in business for some time. Their experience serves as a guide to the extent and nature of investments in additional manufacturing facilities. With the many changes that have taken place in products designed with greater regard for efficient manufacture, the improved manufacturing equipment which has become available, and also improved processes, there has been little need for additional manufacturing space. Economic consideration has been given, rather, to modernized manufacturing facilities applying to factory buildings, production equipment, and the layout of the latter. Modernization has become a creed in industry.

Management is rapidly realizing the desirability, from an economic viewpoint, of undertaking plant improvements when manufacturing

activities are slack. At such times, the work can be done more economically, labor is employed which otherwise might be idle, and such activities cause the least disturbance to regular production.

In establishing additional manufacturing facilities, management has the option of investing its own capital, or renting factory buildings or equipment, or both. Modified arrangements of all sorts may be economically sound as, for instance, rental with the option to purchase, which may decrease the risk of having to vacate and also give the purchaser an opportunity to satisfy himself with the property before buying it. Again, we find instances where new factories are erected for a particular tenant who enters into a long lease with or without an option to purchase. In reaching a decision between the rental of a plant or the purchase of it, the following factors are usually pertinent:

Advantages of ownership:

Possibility of increased land values.

Avoidance of rental charge.

Permanency of possession enabling freedom from loss as improvements are made.

In the event that a new plant is erected, it can be made to suit the requirements exactly.

Advantages applying to property owners, as taxpayers and community supporters.

Advantages of rental:

Decreased risk by avoiding investment in unsuitable location.

Less capital required.

oidance of fixed charges, taxes.

GENERAL PLANT ARRANGEMENT

We can best get an idea of the general layout of a manufacturing plant by approaching it from the viewpoint of the various functional activities of the entire plant. Let us consider a plant of medium size, which is completely self-contained and provides for all functional activities of the enterprise, aside from distribution involving local warehousing, service, and sales locations. Such a plant must provide facilities for performing these main functions, all requiring space and equipment, as follows:

s, to be occupied by the administrative, executive, and clerical ice.

Power plants, for the production of power, if such is not purchased, and heating and ventilating.

Employees' welfare quarters, which may include such facilities as cafeterias, recreation and rest rooms, emergency hospitals, and even an auditorium and athletic field.

Garages and parking lots, to provide facilities for employees and visitors.

Warehouse facilities, for raw, semi-finished, and finished products.

Transportation facilities, including railroad trackage and truckways, with necessary platforms for loading and unloading materials.

Manufacturing facilities, for handling and processing products in the course of production. Obviously, in most plants the greatest space and the largest amount of equipment are required to provide manufacturing facilities.

Each of these different facilities must, in the interests of economy, be provided with relation to the others. Offices must be easily accessible to employees and visitors, as must likewise garages or parking lots and facilities for employees' welfare. The power plant must be located principally with respect to saving losses in the transmission of steam and electricity, and eliminating as much costly cartage of fuels as possible. Transportation facilities must be placed so as to handle all materials which come into the plant or leave it, in an efficient manner. The greatest attention must be given to the location of manufacturing facilities, however, for here we have the center of greatest activity.

G. A. Van Brunt, "How to Make Your Old Plant Better," *Factory Management and Maintenance,* April, 1938, p. B61.

An excellent chart showing the general arrangement of the Buick motor division plant, appears in *Mill and Factory,* June, 1938, between pages 186 and 187.

THE PRODUCTION LAYOUT

In following raw materials through to the finished product, we find, from a manufacturing standpoint, that value is added to the materials in the form of processing and handling, both of which involve labor and overhead. This represents value added by manufacturing. The physical manner in which manufacturing is set up will determine greatly the cost of this added value.

Before launching into any discussion of production layout, it must be pointed out that the problems in this respect are by no means limited to the establishing of a new plant. Factory management is

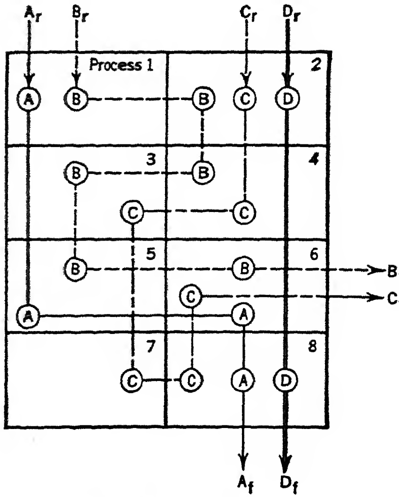

FIGURE 1. Manufacturing on a process basis, showing eight departments, each doing one particular process only. Each circle indicates a processing operation on the particular product indicated by *A*, *B*, *C*, or *D*.

often confronted with the revision[10] of an uneconomical manufacturing layout, or it may have to meet the needs of expanding output[11] under conditions where space is definitely limited. Many enterprises started with simple manufacturing processes that required very little planning to establish. As the plant and processes grew more complex, more machines were put in, and, quite naturally, they were located wherever there was space for them. As a result, in the flow of materials from raw to finished state more time was spent in transit between processes than in processing itself. Haphazard layouts of this kind must be revised for economical continuation of production. Similarly, plants have been built with little provision for expansion, so that, when the need for expansion comes, only a revision of existing layout will allow for it, the problem being one of greater utilization of a given space.

Let us consider a plant manufacturing four different metal-fabricated products, which we shall call *A*, *B*, *C*, and *D*. Each requires certain operations, such as machining, grinding, buffing, punching, finishing, and assembling, which we shall designate by number. Figures 1 and 2 illustrate the two extremes of layout in which each product might be completed. In Fig. 1, we have a plant set up in eight separate departments, each of which performs one processing operation only. By following the four products from raw materials (designated by A_r, B_r, C_r, and D_r) through to the finished state (designated by A_f, B_f, C_f, and D_f), we see how materials in such a layout must move from department to department as manufacturing proceeds.

On the other hand, Fig. 2 consists of four divisions or departments, each of which is set up to process *completely* one of the products from

"Laid Out to Handle More," G. V. Pollard, *Factory Management and Maintenance*, April, 1938, p. 52.

"Compact Efficiency from Modernization," *Mill and Factory*, r, 1937, p. 81.

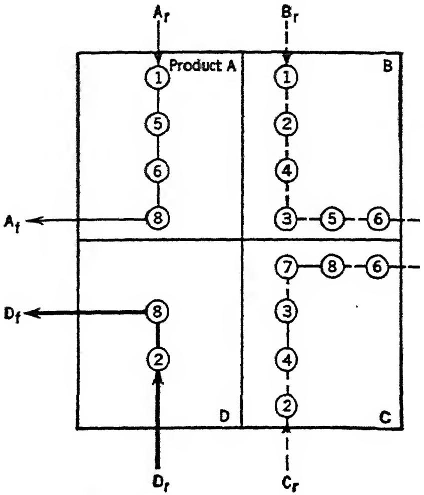

FIGURE 2. Manufacturing on a product basis, showing four divisions, each with facilities to process a particular product completely. Numbers in circles refer to operations shown on Figure 1. Note that relatively little handling is required.

raw materials to finished article. This requires a set-up for the materials to flow, in the same sequence as in Fig. 1, through the various processes, but all processes required for one product are confined to a single division or department.

These two extremes are termed "process control" and "product control," respectively. A layout for manufacturing on a basis of process control, hence, is purely departmental as regards processing; on the basis of product control, there are many "inner factories" within the main plant, each having facilities by which a continuous flow of materials through the required processes is accomplished as a single unit.

Our concern with manufacturing layouts in this book relates to principles of the most economical way of setting up production. To arrive at such a layout, we must balance the economic advantages of each system—that is, process or product control—and select a system or combination of systems which is most economical.

The advantages of the functional or process method of layout are:

Fewer machines needed for an equal number of product lines and volume of business, since all operations requiring a particular process are done in one place.

Specialization of workers and supervisors resulting in greater efficiency, owing to their concentration on one line of work.

Simplification of departmental layout as well as facilities for maintenance and repair, since only one general class of machines is to be dealt with in one place.

Simplification of power transmission and higher load factor on machines, since one department handles all the work required in a given process, such as grinding, punching, or buffing.

On the other hand, the advantages of operating on a product control basis [12] are:

Greatly reduced amount and simplification of plant transportation and handling, because the product passes directly from one operation to another in close proximity.

Where handling cannot be completely eliminated, it can be mechanized with simplicity, owing to closely adjacent processes.

Elimination of inspections, temporary storage, counting, and other operations necessary each time materials transfer from one department to the other in a process control layout, since various processes are not independently operated.

Increased turnover since prompter delivery is accomplished by the product proceeding from operation to operation with the least delay.

Stocks of semi-finished and finished materials in process of production are reduced.

Clerical work and operations such as scheduling, routing, dispatching, and recording are reduced.

Definite placing of responsibility for quality and rate of production of product is possible, since all operations are under the immediate responsibility of one supervisor.

Great reductions in total processing time are brought about through the large reduction in handling time.

From a careful study of these advantages of the two systems of plant layout, one sees that there must be a careful and unbiased balancing of all economic factors so that an economically wise selection for the general scheme of production layout will be adopted. With few exceptions, the resulting layout is a combination of both product and process control, the scheme varying with the variety of products built, existing and anticipated volume of business, relationships of products to one another, and the nature of the products. The layout selected should represent a maximum of economic advantages in the interests of minimum production costs.

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L. K. Urquhart, "Bee Line Flow with Room to Grow," *Factory Management and Maintenance*, October, 1938, p. 52.

art showing the complete layout of the Detroit Diesel Plant of the General Motors Corporation, *Mill and Factory*, June, 1938, between pages 138 and 139.

lan H. Morgensen, "Plant Layout," *Factory Management and Maintenance*, May, 1936, p. S245. An excellent treatment of the layout for production.

A. F. Murray, "A Case in Small-Plant Layout," *Factory Management and Maintenance*, June, 1938, p. 61. An example of a small self-contained plant within a large main plant.

[12] Reference: "Laid Out to Handle More," G. A. Van Brunt, *Factory Management and Maintenance*, December, 1937, p. 79. This article illustrates the product control basis of production in an actual concern.

PROCESS FLOW CHARTS AND FLOW DIAGRAMS

The process flow chart and flow diagram are indispensable tools in studying a proposed production layout or revising an existing one. A *flow diagram* or flow sheet is merely a floor plan of production facilities drawn to scale, on which are located all points of processing and the route the materials take from raw to finished condition. Accompanying the flow diagram is a *flow chart* which also follows a product through the steps of manufacture by listing vertically, with the aid of symbols,[13] all operations and each individual act of inspection, transportation, or storage in the sequence in which they occur. Opposite each symbol for an act of transportation is indicated the distance moved, and after each operation symbol, a description of that operation.

Using these two tools—the flow chart and flow diagram—one is able to visualize every move made in product manufacture and the amount of handling and processing involved. Several schemes can thus be accurately compared in seeking the most economical arrangement for processing, once the general method has been selected.

In using flow charts to arrive at an economical layout, each symbol should be closely scrutinized, and these questions asked about each:[14]

1. Can the operation be eliminated?[15]
2. Can it be combined with another operation?[16]
3. Can the sequence be changed?[17]
4. Can the particular operation be simplified?[18]

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[13] Developed by Frank B. Gilbreth, the more simple of these symbols are:

◯ —Symbol for an operation.
○ —Symbol for a transportation.
▽ —Symbol for a permanent storage.
▼ —Symbol for a temporary storage.
□ —Symbol for an inspection.
Ⓒ —Symbol for a transportation by conveyor.
Ⓔ —Symbol for a transportation by elevator.
Ⓗ —Symbol for a transportation by hand truck.
Ⓚ —Symbol for a transportation by electric truck.
Ⓜ —Symbol for a transportation by man.

[14] From "Plant Layout," Allan H. Morgensen, *Factory Management and Maintenance*, May, 1936, p. S251.

[15] One company developed a highly efficient record system for a process, but closer examination showed that the operation was unnecessary for the work actually required could be done by one man and a duplicating machine, instead of five clerks.

Another company eliminated transporting materials long distances to and

With the aid of such flow charts and flow diagrams, savings are often put into effect that would remain unrecognized if the processes were not thus viewed on paper. A definite economic perspective [19] is obtained that is not possible merely by viewing the actual operation. Many plants go further and use models of their proposed process layouts in addition to the charts and diagrams, and often the flow diagram is an isometric view if multi-story production plants are involved.

REFERENCES

LEWIS K. URQUHART, "All Flow, No Ebb," *Factory Management and Maintenance*, March, 1938, p. 63.

LLIAM T. CONNORS, "Pay-Off on New Layout—150 Per Cent," *Factory agement and Maintenance*, July, 1937, p. 57.

FUNDAMENTAL FACTORS IN PRODUCTION

Having established in our minds the general conditions and methods under which an enterprise is to operate, we will next consider those factors which directly influence physical production. Such factors are either:

Beyond the control of production [20] management, or
Within the control of production management.

We shall study each group of factors separately.

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from a drilling machine by installing a portable drill on a machine doing another process. This also eliminated one man at the drill.

[16] A manufacturer, in studying the flow diagram of his product, noted that the production line had to be interrupted and the part in process of production carried to an inspector's table to test for thickness. By the installation of an automatic recording thickness gauge on an adjacent machine in the production line, the inspection was combined with the operation, thus eliminating delay, storage at the inspector's stand, and transportation to and from the p

[17] A flow diagram disclosed that one product in a certain plant left a shearing machine, passed a drilling machine in being transported to a punch press, only to return to it for drilling after the punching operation. This backtracking was eliminated when it was found practicable to drill the material before punching it.

[18] A manufacturer observed an operation wherein six holes were being individually drilled by an operator. The operation was simplified by the installation of a multiple spindle drill which, by one setting, drilled all six holes at one time, with the resultant simplification and saving in labor.

[19] Process flow charts and flow diagrams are illustrated in their application to finding the most economical production layout, in Economic Study III, Chapter XVIII.

[20] *Production* management has to do only with production, not the general management of the enterprise.

FACTORS BEYOND THE CONTROL OF PRODUCTION MANAGEMENT

Those factors which influence production and are beyond the control of production management relate to volume, variety, and continuity of product load, the altering character and quality of the product, and variations in delivery demand.

In illustrating these factors it is well to bear in mind that orders given the manufacturing plant may be of two general varieties:

> *Orders for stock,* that is, orders covering standardized designs that are built for warehouse demands, to be sold to customers as they need and order them.
>
> *Orders for customers,* wherein the product usually consists of special apparatus, or standardized apparatus not ordinarily built for stock.

It may assist the visualization of the factors beyond the control of production management to consider a builder of small air and refrigeration compressors.

Volume. The volume of orders supplied a productive plant will have a definite reflection in the unit productive cost. Assuming other conditions constant, if this plant devoted to the production of small compressors operates at a factory load for which it has been laid out, it will operate more efficiently, and hence the unit costs will be lower, than if the factory were underloaded or an attempt were made to overload it. The elements of variable costs which constitute labor and materials would, within reasonable limits, remain unchanged when considered from the viewpoint of *unit cost,* as the factory load decreases. On the other hand, the fixed costs, such as established overhead expenses, would not decrease to any great extent, and consequently each unit produced would have to be charged with a larger share of these indirect fixed expenses, in view of a decreasing number of units produced. Hence, operation below full load usually results in high unit costs.

Factory operation, from the point of view of load, may be compared with the load imposed upon such a machine as an electric motor. For instance, an electric motor designed to develop 5 hp. as full-load rating operates less efficiently under a load of 2 hp., or when a temporary load of 7 hp. is imposed upon it, than it does when operating at its rated load. Losses within the motor itself cause a lowering of efficiency when it is not operated at the load for which it was originally designed. In a similar way, if the productive plant were designed to produce 100 compressors in a normal working day, decreased efficiency in operation would result if the plant were loaded with only 50 com-

pressors a day, of if an attempt were made to produce 150 compressors per day.

Variety. If, in the plant building compressors, we made only one type and size, other conditions being equal, we would obtain a lower unit cost per compressor, not only because we would employ the principle just stated of having a larger volume per type and size, but also because a gain would be made in such items as simplification in plant layout, equipment, and operation, all of which would represent a saving. Greater variety of productive load, therefore, increases the cost per unit produced.

Continuity of Operation. Should the productive load of compressors based on order continuity be continuous or consistently the same, lower costs would be obtained than if the production rate were variable. Labor could be retained, operators would have no tendency to lose skill through idleness, machines could be well loaded, and other such savings could be maintained. Since fixed costs go on, with but slight variations, even though the factory load falls off, continuity of orders will result in a minimum unit cost.

Altering Nature of Product. Changes in the design of the product present another factor beyond the control of the manufacturing or production management. It may be the policy of the *general* management of the company to pioneer in the design of new products, or, on the other hand, competitors may force such changes. For instance, in place of reciprocating compressors for certain classes of service, new designs of high-speed centrifugal compressors may be required, and the factory management must prepare itself to build this altered product, which, of course, involves expenditures. Such a change would probably necessitate new equipment and new processes of manufacturing involving the training of employees, and, for the time being, decreased factory output. Such changes obviously are necessary with most enterprises and in most factories; otherwise future production would finally be curtailed through lack of demand for products no longer saleable.

This same condition might confront an enterprise operating more than one plant. Large compressors, for instance, might be built in one plant and small compressors in another. It is quite possible, with an increased demand for small compressors for the air-conditioning and small commercial refrigeration market, that the plant building these might become overloaded and hence experience high costs. A solution to this problem might be to move the manufacture of some of the larger designs of small compressors to the other plant, and thus relieve the at the small compressor plant.

Quality Factors. Quality factors are based upon the policy set and maintained by the *general* management of the enterprise, and the demands of the kind of market which the general management chooses to serve. Products of high quality usually cost more to build than ones of low quality. Here again is a need for an economic balance. Too high a quality standard means high costs of precision manufacture; too low a quality standard results in few orders and hence high unit costs.

Delivery Demands. The requirements as to promptness of delivery are also established by the market and are beyond the ordinary control of production management. For instance, a large compressor of special characteristics which must be individually built might have to be delivered in six weeks to meet the date desired by a purchaser or offered by a competitive bidder, whereas the shop or production management knows that twelve weeks is the most economical time in which to make delivery. Delivery in six weeks is more costly than delivery in twelve weeks because special attention must be given to this particular order and other production may have to be delayed in order to finish the job in six weeks. Not only can too short but also too long a delivery time be expensive to operations. Lengthy delivery time results in decreased turnover and hence less economical operation.

FACTORS WITHIN THE CONTROL OF PRODUCTION MANAGEMENT

In considering production, such as the manufacture of a class of equipment, certain main functions are seen to be performed, each of which has interest from an economic standpoint. These functions are:

Selecting, installing, and maintaining manufacturing equipment.
Obtaining, storing, and utilizing materials.
Labor performed on materials in process.
Assembly of the finished product.
Transportation of raw, semi-finished, and finished materials.
Keeping records on materials, operations, and processes.
Testing the finished product.
Inspection.
Providing facilities for power, heat, ventilation, light, water, janitor service.
Disposal of waste.
Storing finished materials.
Shipping.
Recovery of waste.

Each of these functions will now be considered.

Selecting, Installing and Maintaining Manufacturing Equipment. Production management finds one of its most complex economic problems in selecting production equipment. Broadly, we know that economic results of manufacture can be obtained only with machinery best fitted to its purpose, properly integrated with other production factors, and kept in a condition for maximum operating efficiency.

The principal considerations in selecting equipment for production are as follows:

> The machinery must be fitted to do its job in a simple and efficient manner, in a minimum of time, and with as little manipulation and supervision as possible. Primarily, this is an engineering application problem, but economic limitations must be placed on the cost of such advantages.
>
> Machinery should be as versatile as possible. Idle machinery is expensive, and a machine that can be utilized on two or more jobs is not likely to remain idle long. Specialized machinery can be developed, but its initial and maintenance costs are high compared to those of machines of a more standardized design.
>
> Obsolescence and depreciation must be considered in selecting machinery of any kind, and specialized machinery in particular. Anticipated trends in newly available machines and methods, as well as changing demands of the market, should be studied to make reasonably sure that the selection will not become suddenly obsolete, resulting in greatly increased costs.
>
> Standardization is a prominent economic consideration in equipment selection. Not only does standardized equipment result in greater machine versatility, but also it reduces the cost of maintenance and repairs, and engenders a uniform method of machine operation in which workers need less training and are able to operate several machines. Too often, machinery is purchased on a cost basis irrespective of make, when, by standardizing on one make of machine, great savings could be achieved.
>
> Frequency of operation often dictates whether it is more economical to do an operation by hand or with a machine. Again, frequency may be the deciding factor in specialized *vs.* standardized machines.
>
> Cost of installation and the ability of a machine to fit into the physical scheme of layout are economic considerations.
>
> Safety in the machine selected has an indirect, but definite, advantage in reducing lost time, compensation for injuries, and medical care for the workers.
>
> The effect a machine may have on surrounding equipment must be considered. For instance, a machine may cause excessive vibration which is damaging to the factory building or to other machines and processes. Again, its excessive noise may reduce the efficiency of the workers. All these have an economic bearing in selecting the right machine.

Aside from the economics of selecting productive equipment is the importance of maintaining it, once it is installed. Almost invariably regular maintenance is cheaper than repair, and is the means of reducing repair and renewal costs. Maintenance should be systematically carried out,[21] even in times of business depression. It is common today to find high costs in industries that have deferred maintenance so long that economical operation is no longer possible without making huge expenditures for repairs and new equipment.

Obtaining, Storing and Utilizing Materials. Materials in raw,[22] semi-finished, and finished form may be required to form a part of what is produced, or for indirect use in the productive process. Every phase of their selection and use must be considered if costs are to be kept at a minimum. Chief among the considerations are these:

> Materials must be exactly suited for the purpose. In order to get such materials, it is necessary to know exactly what is required and the form most economical for use. A system of checking their suitability before they are accepted must be adopted and followed. Costs rise rapidly when processes have to be altered on account of substituted materials.
>
> Markets for all materials must be carefully watched, and orders placed at the time, place, and in quantities which will result in lower costs.
>
> Stocks of materials must be recorded in a running inventory. This enables ordering at the proper time to prevent high costs due to excess stock, or delays due to replenishing depleted stocks.
>
> Materials must be conveniently stored near to the point of use, taking into consideration cost of handling, time required to secure materials for an operation, and other such economic aspects. The advantages of several decentralized storerooms for materials *vs.* a single centralized storage system must be considered.[23]
>
> Materials must be safely stored. Great losses have occurred from damage to or deterioration of materials in storage, and even from theft.
>
> Materials must be issued under a system by which a close check can be kept of the use to which they are put. Many companies each year write off huge losses which occur through waste due to the purchase of materials no longer necessary because of some change in requirements.
>
> Standardized materials should be employed wherever possible to reduce costs and the expenses caused by carrying a greater variety.

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[21] References: "No-Alibi Maintenance," J. W. Brussel, *Factory Management and Maintenance,* February, 1939, p. 72; "Maintaining the Budd Plant," E. Quinn, *Mill and Factory,* April, 1938, p. 64; "Modern Maintenance Saves Thousands of Dollars at S K F," *Mill and Factory,* May, 1938, p. 74.

[22] Reference: "An Example of Types of Raw Materials and Supplies Used in Manufacturing," *Mill and Factory,* June, 1938, p. 96.

[23] Reference: "Twelve-Time Turnover Halves Stock Costs," Fred Pyper, *Factory Management and Maintenance,* May, 1938, p. 78.

These are the main economic considerations in securing materials for productive purposes, although in Chapter XII, which deals with purchasing, we find that various savings are made through efficient buying.

Labor Performed on Materials in Process. Having considered materials, we find the other factor of *prime cost* of a product to be direct labor. Direct labor is labor done directly on the material in the manufacturing process, such as machining, grinding, buffing, painting, and assembly. This type of labor constitutes a goodly share of the prime costs of a product and represents a definite value added to the materials. The actual value added by direct labor depends upon the quality of the work done and the increased utility of the material after having labor performed on it. The value added is not necessarily the wage paid for this labor, and the two should not be confused. Ordinarily, however, the maximum limit for wages for direct labor is set at the value added to the product by such labor. Wages and problems relating to the worker are discussed in the next chapter, as well as Chapter III.

Conditions for manufacture, productive equipment, and materials should all be provided in the scheme for production such that, for a given expenditure of human effort upon materials, the maximum value will be added to the product. This requires continual revision in the methods of applying and supervising labor.

Assembly of the Finished Product. The manner in which a product is assembled may have a pronounced economic effect. Assembly must be performed efficiently and by labor suited to the responsibilities of the task. Close synchronization of assembly with production schedules will eliminate either delays on the assembly line, which may slow production, or idle time at the point of assembly, due to assembly schedules being faster than production. Assembly should be an uninterrupted process with required parts available at exactly the time and place required. Likewise, assembly must be competently performed, since a poorly assembled product results only in loss of all that has been done, or disassembly and reassembly of the item under expensive conditions.

T. G. LAUFER, "Assembly Analysis," *American Machinist*, January 12, 1938, p. 9.

Transportation of Raw, Semi-Finished and Finished Materials. The economics of plant transportation and materials handling involve many important factors:

Time. Materials must be quickly transported so that expensive delays in waiting for materials will be reduced to a minimum.

Relation to other operations and to safety. The transportation system must interfere as little as possible with productive processes. In many plants, overhead transportation eliminates all possibility of injury to employees and leaves floor space free from moving trucks.

Plant transportation must be suited to the product, that it may be safely, quickly, and easily moved with a minimum of loss and damage.

Adequacy. Plant transportation should be selected with an eye to anticipated as well as present demands, since changes and additions to the system are costly.

In a given plant, an economic study should be made to determine the time and expense of all transportation operations, in order to establish the economy of installing mechanical systems, and to select the system that will achieve the greatest saving.

J. O. LANCASTER, "More Conveyors Increase Kelvinator Capacity and Efficiency," *Mill and Factory,* July, 1938, p. 50.

ARTHUR VAN VLISSINGEN, "Handling in Ford's New Tire Plant," *Factory Management and Maintenance,* October, 1938, p. 44.

J. K. NOVINS, "Conveyor Assembly Lines for Hand-Crafted Products Increased Production Efficiency 60%," *Mill and Factory,* February, 1938, p. 85.

STEPHEN E. WELLS, as told to FRANCIS A. WESTBROOK, "Processing Costs Greatly Reduced by Mechanical Handling," *Mill and Factory,* August, 1938, p. 78.

Keeping Records on Materials, Operations, and Processes. Only by knowing what is on hand, what is needed, and what is being done, can the costs of manufacturing be controlled. Records are necessary from the time an order enters the shop until it is shipped, and must involve every phase of the work done and every material used. However, it must be emphasized that an economic balance rests between the costs of keeping records and the use to which they are put. Too many companies establish so complex a record system that the purpose of records is defeated by the high costs of keeping and interpreting them. Record keeping should be standardized in procedure so that as little effort as possible is needed to maintain them.

W. C. ZINCK, "Quick Deliveries Because . . . ," *Factory Management and Maintenance,* October, 1938, p. 49.

Testing the Finished Product. Many products require performance tests before they are released for delivery. Such tests are vital in

that they establish the quality and ability of the product to perform, resulting in satisfaction, which has, in itself, a great economic value. Tests also bring out inefficiencies in manufacture which, when corrected, result in lower costs.

Testing should be as simple as possible and should be in the hands of thoroughly competent men. Procedure should be standardized and according to established limits and specifications which are exacting enough to maintain a quality product, yet not so strict as to bring the costs of manufacture unreasonably high in order for the product to pass the test. Records of all tests are necessary for future reference in cases of apparatus failure, and for determining the trend in quality.

Inspection. Whereas testing is done to establish performance, inspection is for the purpose of seeing that what has been done comes up to a preset standard. In every step in manufacture and construction, inspection insures a satisfactory basis for further procedure. Hence, inspection occurs at periodic intervals and with sufficient frequency so that the results of an additional step can be fully checked. Systems of inspection used in production usually involve the following:

Inspection of raw, semi-finished, and finished materials used in production, to see that they meet a preset quality standard.

Inspection of a product "in work" involving inspection of component parts as they proceed in processing. Such inspection may eliminate much waste by finding errors or poorly performed jobs while they are still correctable, and before too great a value has been added to them.

Inspection of the finished product to make certain that it meets a preset standard of form or performance in every detail.

Inspection should be divorced as much as possible from production, so that it will be unbiased and sufficiently critical to maintain a high degree of quality.

Inspection of machining operations and other "in work" inspections should point out inefficiency in processing, and show the way to cost reductions by correction. Inspection should place responsibility for defects, flaws, and errors where it rightly belongs.

Inspection, just as testing, must follow standard procedure and limits. A balance must be found in all tolerances and limits, between cost of maintaining such limits and product quality. Too often, the inspection department is the source of higher costs by unreasonably exacting demands or too much leniency.

Inspection is costly, for it usually requires the attention of individuals. The frequency and extent of inspection must, therefore, be kept in economic balance with the value of the results obtained in the elimination of losses.

Inspections must be recorded for future study and product control.

Providing Facilities for Power, Heat, Ventilation, Light, Water, and Janitor Service. The manufacturer is interested in providing such facilities as these at the least cost, and yet in sufficient volume and in a form which is economically most useful to production. Power may be purchased or generated in the plant, depending on the relative costs and quantities required,[24] and it must be made available whenever and wherever needed. Heat, ventilation, air purification, light,[25] and water are requisites of production; [26] moreover, the manner and quantity in which each is supplied may greatly affect worker efficiencies, product quality, and physical characteristics of materials. Air conditioning is rapidly being adopted in manufacturing plants for its economic contribution to efficiency and quality in production.

Before deciding on the supply of each of these facilities, production management spends a great deal of effort arriving at the most economical source, quantity, and nature of each—studying them all in respect to their economic effects on product, process, and worker.

REFERENCE

J. HARTWICK, "Plant Services in a New Plant," *Factory Management and Maintenance,* September, 1938, p. 68.

Disposal of Waste. In many plants, this is a minor problem owing to the type of processes involved. In others, it is a major economic consideration. Some steel mills with tremendous quantities of slag often must transport it long distances for disposition. Chemical plants often have corrosive waste products which are costly to dispose of. We have witnessed many plants which have located on rivers where they have economically disposed of their waste products, only to find that legislation and public feeling against water pollution are rapidly making such disposal an impossibility. Lawsuits have proved costly to many manufacturers in waste-disposal problems.

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[24] References: "How to Compare Generated and Purchased Power Costs," *Power,* May, 1937, p. 251; "Power Bills are Lower Now," James J. Wenner, *Factory Management and Maintenance,* February, 1939, p. 80; "Like to Cut Power Bills?" John F. Moore, *Factory Management and Maintenance,* January, 1939, p. 80.

[25] Reference: "Does Good Lighting Pay?" Part 2, Dean M. Warren, *Mill and Factory,* February, 1938, p. 74.

[26] Many industrial processes require large quantities of heat, water, light, and air for evaporation. Of increasing importance in many processes, and also for commercial activities, is the elimination of dust and dirt. There is an increasing use of mechanical air filters in connection with all types of ventilating equipment. Recently electrical precipitation has been increasingly employed not only for industrial processes to reduce hazards and recover material, but also to reduce losses in manufacturing plants and in the handling of merchandise.

Storing Finished Materials. Materials and products, once finished, must be cared for and protected from loss and damage, and must be readily available when needed for delivery. Means for doing this economically must be maintained, and a close check must be kept of everything put in or taken from storage. Ordinarily, to save confusion and damage, as well as to expedite delivery, it is found most economical to pack finished products for shipment or delivery before storing them. They are then ready for release without further preliminaries. The most economical manner in which this function can be performed depends, of course, on volume, type, and variety of products, length of storage period, and other such factors. The aim is to establish a balance between a sufficient stock to assure prompt delivery and a small enough stock so that investment tied up in it is not excessive. However, this is largely a problem of coordinating production and demand, and not one of storage.

Shipping. The final act of a production process, namely shipping, should be given the same degree of economic consideration as the initial act of selecting machines or materials. To maintain prompt and safe deliveries, only responsible means of transportation should be considered. Transportation costs, whether paid by the purchaser or manufacturer, should be balanced with the degree of excellence of the service in deciding on an economic method of shipping. Damages and delays brought about by inefficient shipping service cause inconveniences and often costly delays to purchasers, which may be reflected in the loss of valuable future business.

The product must be packed and otherwise made ready for shipment so that damages and losses are least likely. This is the duty of the shipper, and the added costs of proper packing and protection in transit usually are more than repaid by the customer's satisfaction in prompt and undamaged delivery of his order. Special or large machinery may require extensive facilities for shipment which are reflected in the total costs of the apparatus.[27]

Recovery of Waste. A study of wasted time, effort, and materials constitutes one of the greatest opportunities for any enterprise to avoid

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[27] The huge 200-in. telescope lens for the Mount Palomar Observatory stood 17 ft. 7 in. above the railroad track when ready for shipment, requiring that 1000 bridges be checked for clearance between Corning, New York, and Pasadena, California. In fact, the original specifications were for a 300-in. disc of glass, which had to be reduced to 200 in. when traffic experts warned that it would stand almost 8 ft. higher than the average railroad bridge.

Large machinery manufacturers are building their own "drop-bottom" flat cars in order to gain an extra foot or so in railroad bridge clearances for huge turbines and compressors which they build. Naturally, such procedure is costly.

economic loss.[28] Eliminating loss in materials[29] that are ordinarily scrapped offers a continual problem for production management. Not only does the material which is scrapped represent a loss in itself, usually including expenses of a direct and indirect nature already applied to it, but additional expenses are involved in the disposal of materials scrapped and accounting for this in records. The object of production management, therefore, is to study continually material items which are cast aside from processes of production, use them elsewhere in productive processes in an existing or modified form, or else process them[30] so that they will bring the highest price on the open market.[31] In certain industries where raw materials are processed to obtain a desired product, the disposal of by-products assumes a matter of major importance, involving a study of product modification and market developments. Many companies, through a study of by-products, have arrived at the point where the by-product is no longer a loss but an item of profit, and therefore assumes a rank equal to the product initially selected for manufacture.

In the manufacture of physical objects such as all classes of machinery, equipment, and supplies, production management commonly takes these steps to eliminate waste in materials:

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[28] This is an excellent example of "the little things" that save in a process:

> In the early days of the Standard Oil Company, the late Mr. Rockefeller visited one of the refineries and stopped to watch the intricate machine that was soldering on the tops of the filled oil cans. Presently it developed that he was counting the drops of solder used by the machine on each can: 39 drops exactly. Mr. Rockefeller inquired whether anybody had tested the adjustment of the machine to make sure exactly how much solder was needed. No; nobody had. But then and there a test was made, from which it developed that 37 drops were not quite enough, but that 38 drops would hold the can cover as securely as 39. That one drop of solder was worth, to the Standard Oil Company, some $50,000 a year.—From "The Field of Management," Viscount Leverhulme, *Dun's Review*, April, 1938, p. 6.

[29] One company saves $3500 monthly by reclaiming crating lumber from packing crates of incoming materials.

[30] Another company, in dismantling an old power plant, reclaimed 150 tons of magnesia covering taken from hot-water and steam pipes. Since much of the covering came off in broken pieces unfit for use, the material had to be processed by shredding, mixing with water, and molding into blocks, after which the blocks could be used as insulation for boiler drums, hot air ducts, and so on. Cost of reclamation was about one-third the cost of new material of equal insulating value. Reference: "Detroit Edison Salvages 150 Tons of Insulation," E. T. Cope, *Power*, January, 1937, p. 18.

[31] Waste paper is commonly sold to recover some of this loss. One company, however, goes further and segregates its waste paper into grades, instead of baling it all together. Since as much as $10 difference in price may exist per ton between common grades of waste paper, greater returns are thus made.

It establishes an individual or small group to study the salvaging of materials otherwise wasted.

It promotes, with every employee, the desirability of eliminating all forms of waste, often establishing contests and rewards for suggestions.

REFERENCES

W. H. DOERFNER, "Dramatize Waste Dollars," *Factory Management and Maintenance*, September, 1938, p. 64.

J. MANUELE, "Our Scrap Pile is a Profits Pile," *Mill and Factory*, August, 1938, p. 64.

CONTROL OF PRODUCTION

Attention has been given to the economic aspects of each production activity, and we are impressed with the variety of functions involved. How are all these functions coordinated when an order comes in? This can best be shown by actually following an order given to a typical large equipment manufacturer. We shall outline, in sequence, the progress of the order after it has been received and approved by the headquarters sales and credit organizations:

1. From sales, the order goes to the *engineering department*, where it is assigned to an engineer, who segregates it into new apparatus requiring development work, and standardized apparatus. Drawings are made and manufacturing information necessary for the shop is determined for the non-standard apparatus; for standardized apparatus, the engineer marks the order with the style or order number by which the apparatus can be selected from stock or production.

2. An order next goes to a *clerical engineer*, who indicates on it the necessary manufacturing information and drawings, as well as a complete bill of materials and list of processes.

3. The order, containing this information and accompanied by all drawings, goes to the *layout and routing department*. Here each participating manufacturing section is indicated, a complete routing of materials from the first to final operation is drawn up, and drawings needed are sent to the sections where they will be used.

4. The order, manufacturing information and routing go next to the *production department* where completion dates are assigned each manufacturing department or section involved in the processing of the apparatus, these dates representing the time each section must finish its job and ship the apparatus on to the next processing section. The production department also prepares material requisitions and toolroom orders which are sent to storerooms and toolrooms so that tools and materials will be ready when work is ready to begin. The order is marked upon a "schedule board" on which its progress is carefully followed.

5. The order now goes to the *shop* where it is assigned to a *production clerk* who must see that component parts of the order flow into the assembly section from "feeder sections" as scheduled. When every piece of material is received in the assembly section, final assembly is made, after which the order is tested, given final inspection, and shipped.

As work progresses, records are sent to the cost department, indicating costs of materials used and direct labor costs. The cost department adds to these the burden of overhead which the order must bear, thus arriving at the total cost of the order.

Charts are kept of work being done in every division and section, and on each machine, as well as charts on which the order is followed in its progress toward the promised date of delivery. Floor space in the large manufacturing aisles and work in sections doing heavy machining are scheduled months in advance. The production clerk, likewise, can tell at a glance from his records and charts how any one of his orders is progressing. Such checking systems are expensive, to be sure, but they have an economic return, since delivery dates are accurately predictable, and the "load" on the plant is kept within control and can be manipulated advantageously to reduce costs.

The responsibility for coordinating all functions may rest with a "production control" department set up to coordinate machines, materials, methods, and men; or, again, in other companies, coordination rests with the departments involved.

That production coordination or control is necessary for economic procedure can scarcely be overemphasized. Any attempt to perform all the functions necessary to production without a coordinating plan would send costs soaring as congestion, confusion, waste, and unpredictable deliveries began to exert their influences.

References

D. E. Flinchbaugh, "Two-Board Control Helps Small Plant Keep Promises," *Factory Management and Maintenance*, February, 1939, p. 60.

George T. Trundle, Jr., "What *is* Production Control?" *Factory Management and Maintenance*, June, 1938, p. 49.

ECONOMIC LOT SIZE

Production management often faces a situation such as the following. A certain quantity of a product is needed each year, on the basis of a knowledge of customer requirements. The product is made by a machine that produces rapidly in quantity. "Setting up" the machine (or making special adjustments of machine and preparing tools) in-

volves a rather high fixed preparatory cost, after which any number of a particular product can be produced in one lot without additional set-up expense. Each time a lot is finished, however, and production stopped, the machine is put to other uses, so that it must be set up again to resume production of the particular product mentioned.

It remains for production management to determine what size of lot is most economical in producing a year's supply of this product. Should a whole year's requirements be made at one setting, or should several smaller lots be made at intervals? This question is answered by balancing the savings in preparatory costs possible through large lots, with the increased costs of storage, insurance, and taxes on large inventories resulting from such large lot sizes, plus a return on the financial investment in such inventories. The lot size selected should be such that, considering a year's supply of product, the total annual preparatory or set-up costs plus annual costs of carrying the inventory will be a minimum.

It can be seen that the problem of the most economical lot size is a vital one to production management on products manufactured in quantities and for stock. Formulas have been devised for calculating the economic lot size, but most of them are exceedingly complex. W. E. Camp's formula is probably the simplest, and is given here as an example of the factors considered in determining lot size. Camp's formula is:

$$Q = \sqrt{\frac{2 \cdot R \cdot S}{I}}$$

where S = set-up cost in dollars; R = rate of consumption per year in pieces; I = interest rate on investment in stock and storage costs, multiplied by cost per piece in dollars (labor, materials and proper proportion of operating expenses); and Q = the quantity of the most desirable lot size.

CHAPTER XI

PROBLEMS OF THE SUPPLIER—PRODUCTION (continued)

MANAGEMENT AND LABOR IN PRODUCTION

In a consideration of production, we find that it takes place through the joint effort of human services and materials. Human services include *labor* and *management,* and materials include *capital* and the *physical location* required for pursuing production processes. All four of these forces are necessary.

When we consider labor and management, we may become confused, for in modern production, between the individual who does nothing but direct others in their operations and the individual whose entire efforts are directed by others, we find a vast number of workers whose performance consists both of following directions laid down, and also directing others. The difference between labor and management is, therefore, a functional difference. This functional difference relates both to the exercising of authority and the definition of duties to be performed.

Labor, in its broadest sense, applies not only to physical but also to mental activities. It represents a form of service which, in our age of specialization, receives its compensation in the form of wages and salaries. In the discussion of production, we will consider labor as representing the wage earner who forms a part of the production process. It includes human effort from the viewpoint of performance along lines of effort established by management. Its responsibilities relate to reliability, speed, and accuracy.

The responsibility of the functions of *management* in production relates to the establishing of tasks, based upon economic decisions of what to do, and the direction and supervision of those hired to perform such tasks. From a practical viewpoint, after a production layout has been established, we look on production management as being responsible for the overall volume, quality, costs of the product made, operating condition of plant and equipment, and relationships between employees and employer. Responsibility lies in the field of directing and maintaining efficient performance. Effective production manage-

ment keeps things going smoothly and efficiently, and also is constantly alert to improvement in output and the saving of cost.

The production responsibility of management is exercised both in the direction of utilizing and maintaining the productive equipment which is at work within the walls of the plant, and also in the maintenance of the plant building itself and in the services which it furnishes to individuals and machines that occupy it, in regard to physical protection, heat, light, and power.

MEN AND MACHINES

In discussing the use of machinery for purposes of production, we have observed that economic production requires the selection of the proper machine to do the work and the establishing of the proper relationships between one machine and another to accomplish efficient production.

Since production takes place through the joint effort of men and machines, it is equally important in accomplishing efficient production to select the proper individual for the work, arrange that his efforts are efficiently directed and timed, and that the proper relationship exists between one individual and another. Because each individual represents a human being, whereas each machine represents only a piece of property, at all times the safety and well-being of the individual must take precedence over those of the machine.

Society has been hesitant in analyzing human effort in the same way and to the same extent as machine effort, because in doing so it has been felt that the individual was being reduced to the level of the machine, and that the sole purpose was to get more work out of him for the same or less pay. This stigma associated with analyzing human effort with exactness, and thus establishing standards of performance, is being largely removed, however, since analyzing the efforts of the individual, no matter what his calling or what the nature of his work, is becoming more clearly recognized as of value to the individual himself in increasing his happiness and earning power.

Frederick W. Taylor was the pioneer in a study of applying scientific principles to human effort in manufacture, and his paper "Shop Management," presented before the American Society of Mechanical Engineers in 1903, started a new era in industrial management, establishing the principles involved in the proper selection of individuals for the purpose intended, their training, and a means of applying and measuring human effort with exactness and precision. The Taylor

Society was subsequently formed, which has amplified and interpreted these original principles, for the benefit of industry.[1]

PRODUCTION MANAGEMENT

Although the *general management* of an enterprise establishes the general policies of the company, which govern its entire operations, *production management* is directly responsible for all phases of production, and the actual condition of the product, its cost, and the time and rate of delivery. On production management, therefore, falls a substantial share of the responsibility for the success of the enterprise.

Production management's responsibilities relate to:

> The manufacturing plant, including the selection, installation, and maintenance of all equipment forming a part of plant or processes.
>
> The employees engaged in all classes of production, including their selection, training, supervision, and welfare.
>
> The establishment of all policies and plans dealing with productive systems.
>
> The quality and cost, as well as promptness in delivery, of product, so far as factors within the control of production management are concerned.

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[1] The "Statement of Principles" as set forth by the Taylor Society in 1929, is:

1. "*Management Research.* Research, investigation, and experiments (with their processes of analysis, measurement, comparison, etc.) constitute the only sound basis for the solution of managerial problems; for determinations of purpose, policy, program, project, product, material, machine, tool, type of ability or skill, method and other factors, and the coordination of these in purposeful effort."

2. "*Management Standards.* To make them useful to an enterprise, the results of research, investigation and experiment must be made available to the cooperating group in the form of defined and published standards which serve as common goals, facilities and methods, and which replace chance and variable factors by constants in terms of which may be made calculations and plans which may be expected to come true."

3. "*Management Control.* There must be established a systematic procedure, based on the defined standards, for the execution of work; a procedure which directs the researches, establishes and maintains the standards, initiates operations, and controls work in process; which facilitates each specialized effort and coordinates all specialized efforts, to the end that the common objective may be achieved with a minimum of waste of human and material energies, and with a maximum of human welfare and contentment."

4. "*Cooperation.* Durably effective management requires recognition of the natural laws of cooperation: involving the integration of individual interests and desires with group interests and desires and of individual capacities with the requirements of group purposes; the substitution of the laws of situations for individual authority, guess and whim; and the recognition and capitalization of human differences, motives, desires, and capacities in the promotion of a common purpose."—From "Scientific Management in American Industry," by the Taylor Society, H. S. Persons, editor, Harper and Brothers, New York, 1929, p. 10.

One can often, in inspecting a plant, get some definite idea as to the ability of the production management, for the condition of the plant and equipment reflects the management, just as the condition of a house reflects the housekeeper. It is remarkable what capable management, just like a thrifty housekeeper, can do with a limited expense budget.

In considering employees, capable management has the following functions:

It selects and assigns the right man for the job.

It gives him the best possible working conditions for performing the task.

It supplies him with suitable tools and machinery.

It teaches him how to use tools and machines in the most efficient ınner.

It rewards him for quality and quantity of work done.

Again, employees reflect management in their skill, energy, and enterprise, since the spirit capable of management is passed down the line to others. Production management must, of necessity, be familiar and in close touch not only with current events in the field of labor, but also with what other manufacturing companies are doing to make workers more efficient and prosperous. Especially is it necessary for capable production management to understand and maintain close and sympathetic contact with employees, discovering the difficulties and problems they encounter, encouraging them and assisting in their development and progress. The stern and threatening boss no longer has a place in industry.

In the establishing of productive systems and carrying out plans for production, management is continually seeking for improvement by experimenting with new methods, discarding those which do not work out successfully and putting into effect newly discovered, more successful methods—all in order that the quality of the product may be increased and its cost reduced.

Besides the responsibilities of production management which have been enumerated, it is of vital importance, both to the success of an enterprise and also to efficient production, that management coordinates the efforts of production with the other activities of the enterprise, particularly product design activities, purchasing activities, and the activities of any central organization established to treat with employee relationships.

LABOR TURNOVER

Labor turnover causes an economic loss[2] that no enterprise can entirely avoid, since, if for no other reason, some employees are constantly withdrawing on account of incapacity or death. The causes for labor turnover,[3] however, are due often to lack of work, or to dissatisfaction for one reason or another on the part of the individual or employer. Earlier in this book, we pointed out that the skilled mechanic has been largely displaced in industry by the machine operator. Since the skilled mechanic included in his work a large number of operations, and his usefulness to an employer related to his ability to perform duties peculiar to a given plant, there was considerable resistance to his moving from plant to plant. Today, however, since machines are standardized, as well as their operation, the machine operator can find employment in a variety of plants which employ machines on which the operator is skilled. Hence, operators may move from plant to plant, and are inclined to do so, unless some means are adopted to tie the individual more closely to one company.

SELECTING AND ASSIGNING THE RIGHT INDIVIDUAL FOR THE JOB

From an economic viewpoint, the importance of the type of personnel of an enterprise cannot be overemphasized, because from human ability all else originates and is directed. The nature of the employee, in his various stations of responsibility, determines the nature of the enterprise, since it is employees who select other employees and supervise them, select and maintain all physical facilities and equipment, and establish methods and tempo of procedure. No better

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[2] It is estimated that one mill spends $2870 per year training employees who remain in the company only a short time.

Reference: "Labor Turnover Can Be Reduced by Proper Foreman Training," *Textile World*, February, 1939, p. 40.

[3] As an average, during each month of 1937 the labor turnover for every 100 employees in representative factories of 144 industries, was as follows:

1.25 employees quit.
0.20 employee was discharged.
2.98 employees were laid off (including temporary, intermediate, and permanent layoffs).

This is an average monthly separation of 4.43 employees out of each 100 employed, while the accession rate (which includes hiring of new employees or rehiring old ones, but not transfers between plants of the same company) was 3.55 employees.—Data from *Monthly Labor Review*, January, 1939, p. 196.

investment can be made by management than in efficient man power. Enterprises grow and prosper by:

The proper selection of individuals.

Assigning the individual to the class of work for which he is best suited.

Training, supervising, and encouraging the individual so that he will develop.

The selection of suitable machines and the assignment of their part in a productive program are comparatively simple, compared with the selection and assignment of individuals, because, since human beings are so complex, the capabilities and possibilities of an individual cannot be evaluated by a physical appraisal like those of a machine. We have established fairly accurately the characteristics an individual should possess for various classes of tasks, but determining from an interview the likelihood of the individual's being able to meet these established requirements is a much more difficult matter. Skill, based upon training and experience, appears essential in selecting men, and certain persons appear to possess a certain intuition which suits them for this work. The selection, obviously, must be based upon a knowledge of the exact requirements of the job, and a knowledge of the individual being considered. To a degree, at least, the selection of workers has been reduced to a science, based upon an interview, a record of the characteristics of the individual and his experience, and, by some employers, a series of simple psychological tests.[4] The selection of individuals is, however, not an exact science by any means, and all that can be done is to reduce error as much as possible.

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[4] Several years ago, early in the summer, a friend of the author who is professor of sociology in an Eastern college applied for work at the employment department of a large manufacturing plant. His intention was to assume the exact position of an untrained workman endeavoring to obtain employment, land a job, and during the summer live the life of a factory hand. His purpose was to observe the methods of selection, training, and supervision practiced by this manufacturer, and gain experience from living for a few months the life of the factory workman.

The employment department of this company examined him carefully as to intelligence and aptitude. He was hired and assigned to a department engaged in forming copper coils, and given the assurance that, on the basis of the examination made, there was a future for him with the possibility of some day developing into a shop foreman. His identity was known only to the director of personnel of this company and the author. When he left the company, he made a favorable report to this personnel director on the methods employed by the company in handling applicants and employees, and suggested improvements of a minor though valuable nature.

Reference: "The Technique of Testing," Charles A. Drake and Holger D. Oleen, *Factory Management and Maintenance,* March, 1938, p. 71. A discussion of aptitude tests in selecting employees.

Every time an individual is employed for an existing job, and then proves unsuccessful so that he either must be released or tried in another place, an economic loss occurs both to the employer and the employee.

Eugene Caldwell, "Personnel Records of Today," *Factory Management and Maintenance,* September, 1938, p. 53.

THE TRAINING OF THE INDIVIDUAL

It is to the economic interest of the employer, and the employee, as well, that the employee becomes more productive. This comes only through a direction of the individual's efforts and through experience in performance. The old method of training men by placing them as helpers to experienced workers has largely been abandoned because, usually, the experienced worker was not a capable, and sometimes not a willing, teacher, and he was naturally inclined to pass off onto the helper minor responsibilities that made his own work easier. Hence, most enterprises have established courses of training and have set aside either departments or a group of instructors, or both, so that employees are trained in a systematic way.

Most companies favor training their employees in this way rather than depending on an outside source as a supply of trained talent, for men so trained become familiar with the company's processes, products, and policies.

Warner Seely, "The Cost of Apprenticeship," *Mechanical Engineering,* December, 1938, p. 901.

SAFETY FOR THE WORKER

The economic loss, due to accidents and disease, both to the worker and to the enterprise has, for many years, attracted the attention of the public and of management. Such a situation has led to action on the part of various organized groups within industry itself and on the part of legislative bodies, and has become articulate in the following ways:

Laws applying to all classes of industrial activities, calculated to prevent accidents and promote health.

Laws directed to compensating workers for losses which occur as the result of accidents while working.

The adoption of standards and rules of safety, relating to equipment,[5] machines, operations, and processes.

Propaganda directed to make workers conscious of the dangers of carelessness, and the value of following rules for safety.[6]

Today, many enterprises employ engineers who give their entire time to matters relating to safety, and the rules applying to all classes of industrial workers are becoming more closely defined and rigidly enforced.[7]

TIME AND MOTION STUDY

It was F. W. Taylor who first brought out the need for time and motion study by showing that the motions of workmen in days past had no scientific basis and were often quite inefficient.

Time study [8] is the study of a particular operation in production, in an effort to find the exact representative time required to do each minute detail of the operation, both manual and mental. Once a representative and accurate timing of an operation has been made, the information may serve three distinct purposes:

It can be used as a base for almost any wage incentive system, by the establishment of a "standard time" for completing any piece of work. We shall see this in use in the discussion of wage systems.

It assists in production control, such as the scheduling of work through the plant, and in the estimation of delivery dates, and has a definite place in "cost" calculations.

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[5] One large company spent $25,000 in two years to reduce eye injuries and saved $116,000 in reduced payments in compensation and the like. Reference: "No One Enters This Plant without Goggles," Harry Guilbert, *Factory Management and Maintenance*, March, 1938, p. 83.

[6] Probably one of the first and most successful drives for safety was on the railroads of this country. "Safety First" has been instilled in the minds of every worker, with exceedingly gratifying results.

[7] Reference: "Safety is a 'Must' for Ford Electricians," *Factory Management and Maintenance*, October, 1937, p. 104. In this article it is pointed out that disregard for safety rules means automatic dismissal.

Other references: "Safety Program Proves Profitable," Otto R. Schuman, *Mill and Factory*, September, 1938, p. 71; "Newport Industries' Safety Policy," E. F. Sisson, *Mill and Factory*, August, 1938, p. 48; "Safety's Silver Anniversary," *Paper Industry & Paper World*, November, 1938, p. 855.

[8] A good definition of the term "time study" is the following: "To subject each operation of a given piece of work to a close analysis, in order that every unnecessary operation may be eliminated and in order to determine the quickest and best method of performing each necessary operation; also to standardize equipment, methods and working conditions; then, and not until then, to determine by scientific measurement the number of standard hours in which an average man can do the job."—From "Time and Motion Study," by Lowry, Maynard, and Stegemerten, McGraw-Hill Book Co., Inc., New York, p. 6.

By studying the various motions involved and the time required to complete a certain piece of work, the best method for doing that job may be determined.

Making time studies requires accuracy and extremely close observation on the part of the person making them. With the aid of a stopwatch, each motion or element [9] of the entire operation observed is carefully timed and recorded to within 0.01 minute. If the elements are extremely small in time, many studies are taken to reduce error to a minimum in the final calculation. Once the data [10] are secured, the operation is thoroughly analyzed, revealing the amount of time that should be allotted to the machine and the time taken by the operator. An average or representative time is set up as a standard for performing the operation, upon which wages, costs, and production estimates can be based. Ordinarily, in setting standard times, a percentage of observed time is allowed for delays and other personal needs of the operator, such as rest. Also, the observed time may have to be corrected for the efficiency of the operator observed. Were this not done, except where representative studies are made with several different operators on one operation in order to strike an average, the standard time set would be too high if the observed worker were above average efficiency; too low, if he were subnormally efficient.

Motion study is related to time study but refers more to the sequence and basic motions in each operation a worker performs. Frequently, motion study is carried out by taking motion pictures of workers performing their operations. Either by including a rapidly moving clock in the picture [11] or counting frames of film when constant-speed cameras are used, each element of an operation can be observed from the film, and the time it requires can be carefully determined to an accuracy of 0.01 or even 0.001 second. The motions of the worker are thus observed and divided up into those recognized as standard by motion-study experts.[12] Less desirable motions can be determined, and their causes ascertained. These may be due to faulty layout of work, generally poor working conditions, or the nature of the work

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[9] An element is a motion that cannot be broken down into any simpler motions.

[10] The data on one comparative time study are shown in Chapter XVIII, Economic Study XVII.

[11] Sometimes termed "Micro-motion" study.

[12] The *motions* have been catalogued and listed in the order of their desirability by various authorities. The most desirable motions are those involving little effort—motions of the fingers, or of the fingers and wrists. The least desirable motions involve much effort, and require a change in posture.

itself. Whatever the causes are, the probability is that some of these undesirable motions can be eliminated or rectified, or perhaps their sequence changed advantageously.

An analysis of this sort is of value in several different ways:

It is an aid in correcting faulty working conditions.

It is of value in cutting down wasted or inefficient motions.

It makes possible a standard set of motions for performing a task.

It allows for the setting up of an extremely accurate standard time.

Since it makes possible a standard set of motions for a task, this in turn permits the training of employees to be more easily and quickly accomplished.

It is the only method for the accurate study of extremely short and rapid movements, and the analysis of these into basic elements.

Our discussion here of time and motion study has been limited primarily to the economic aspects of such functions. It is not difficult to see that the inception of such studies has greatly benefited productive management in reducing costs and increasing productivity of the workers. One of the more difficult things management has to do is to inform employees properly on the subject of why these studies are needed.[13] Many employees see but one object in time and motion studies—more work from the worker with less pay. Actually, these studies may benefit the employee as much as management.

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WAGE PAYMENT SYSTEMS

It has been pointed out that production management is responsible for selecting and training employees, providing them with good working conditions and tools, and *rewarding them for quality and quantity of work done.* We are here interested in the latter function, which is

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[13] In one instance, a bit of the seriousness was taken out of time study and a better understanding and acceptance of it by the workers were achieved by making a time study of an employee taking his daily bath. Every element was timed, and the consumed time found to be 21.40 minutes.

accomplished through a wisely selected system of wage payments. Nevertheless, it should be emphasized that, no matter how excellent the wage payment adopted is, it cannot function efficiently unless these other functions are wisely carried out.

Wages and salaries are of importance to almost every individual, since we are living in an era when the majority of us must earn our living by working for others. The reward we get for our mental and manual functions at a particular job constitutes our salary or wage.[14] In definition, salaries and wages refer to separate classes of employees. That is:

> *Salary* ordinarily is fixed in amount as so much per year, month, or week, irrespective of daily fluctuations in the output of the worker. Usually salaries are paid to employees not directly engaged in production.
>
> *Wages* are ordinarily not fixed, but represent payment to workers directly engaged in production activities, expressed usually in terms of amount of work produced or hours spent on the job.

We are here primarily interested in *wage* payment systems since we are dealing with direct labor in production, as well as office workers and other indirect labor in the factory.

Management is confronted with two main objectives in dealing with wages of labor, which may, at first thought, seem quite impossible to secure simultaneously. (1) Labor should be paid in a manner conducive to *lower production costs*, and (2), it should be paid with an eye to *constantly increasing living standards* of the worker. This is not so difficult to do, however, when we analyze action and reaction. When workers are paid well, a higher standard of living is obvious. Also, well-paid workers, on the average, work at greater efficiency and with much more enthusiasm and interest, thus increasing production rates and reducing both the fixed costs per unit and the wages paid per piece—resulting in *lower production costs*.

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[14] Although we are concerned here with wages in any one specific enterprise as related to efficiency of the worker and the general economic good of the company, we should point out the variation and limitations of wages in general. This is well put in the following quotation:

> Wages vary as to time, place, industry, sex, general price conditions, and other circumstances. Broadly speaking, wages will not be greater than the value added to the product by employees, nor less than the amount needed to sustain workers at the level of subsistence recognized by their group in modern society. Between these inexact limits, wages are determined by the forces of supply and demand. Among the factors involved in the interaction of supply and demand are education, trade unionism, immigration and emigration, social customs, legislation and the state of business activity.—"Economics for Engineers," E. L. Bowers and R. H. Rowntree, McGraw-Hill Book Company, Inc., New York, 1931, p. 274.

Wage systems can be roughly divided into two main classifications:

1. The "day work" or "day rate" method.
2. Incentive plans.

REFERENCE

hen We Get Where We Are Going," an interview of HENRY FORD by ARTHUR VAN VLISSINGEN, *Factory Management and Maintenance,* December, 1938, p. 31. In this article the point is brought out that we will eventually double present wages (1938) by producing better goods at lower costs which will permit them to be sold to twice as many buyers at lower prices.

THE "DAY WORK" METHOD

The "day work" system of wage payment is the simplest since it involves only finding how long a man works and paying him accordingly, irrespective of variations in daily output. Such a system is economically sound where it is costly to determine a man's output accurately, as storekeepers, clerical help, repair men, and others with a great variety of tasks each day. Or, again, a man's output may be relatively easy to compute but his rate of production may depend on conditions beyond his control,[15] making the day rate system the only fair one to him.

"Day work" lans are disadvantageous in that they offer no acknowledged incentive to better and quicker work, and often workers are inclined to develop a system of "appearing busy" while actually getting little done.

INCENTIVE PLANS

It is a trait of human nature to desire reward for accomplishment, and to increase effort when greater reward is assured. The modern incentive plan of wage payment follows this principle, thus increasing productive output and benefiting workers and employers alike.

Any incentive wage plan should be:[16]

1. Just to both employee and employer and ultimately contribute to benefit of both. Reward should be positive and material, not negative nor rily punitive. Operation should promote confidence.

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[15] Workers in automobile plants several years ago objected strenuously to the iece-rate" system under which they were working, since they were paid nothing whenever assembly lines were stopped as a result of conditions beyond their control, such as lack of material or machine failure. So strong was the feeling that management decided, in fairness to workers, to pay the workers on a day rate plan.

[16] Quoted from "Cost and Production Handbook," The Ronald Press Company, New York, 1934, p. 658

2. High in task and reward. Latter should, as one writer aptly puts it, "reflect an employee's contribution to his company's success." Generous reward encourages effort to meet high standards.

3. Sound enough in measurement to guarantee against rate changes until operation method is changed. That is, earned reward will be paid.

4. Reasonably simple for employees to figure or understand in relation to individual or group performance, practical in shop procedure. Results should be available over as short a period as the accuracy of rates will permit.

5. Adapted to augment and be capable of use with other management controls.

6. An aid to teamwork and automatically assist supervision in a practical manner.

Summarizing, any incentive wage plan should be based on a *fair determination of the time and effort to do a particular job*, and the *amount of pay* to be given the worker for doing it.

Our discussion will include only the following more important incentive plans, since the objective of this discussion is to illustrate typical systems of wage payment by which economic results in production may be obtained: [17]

Piece-rate system.
Halsey premium plan.
Taylor differential piece-rate system.
Gantt task and bonus system.
Rowan premium plan.

Piece-Rate System. The most simple of incentive plans, if it may so be termed, is the piece-rate system in which the worker receives a fixed amount for each unit he produces. This system is in disfavor since it assures the worker no guaranteed minimum wage, thus reducing his feeling of security. Determination of what the standard rate of pay per piece shall be is difficult and is naturally contested when, for any reason, a worker's production falls to where he is making insufficient wages for subsistence. Production line "tie-ups" due to lack of materials or breakdown are quite beyond the control of workers, and yet, by the piece-rate system, it is they who suffer the loss. Likewise, workers poorly suited to a task are unable to earn a living wage in competition with more adept fellow workers. Certainly, with

[17] For more comprehensive discussions of the many wage payment systems, the student is directed to such books as "Principles of Industrial Organization," Dexter W. Kimball, McGraw-Hill Book Co., Inc., New York, 1933, and "Cost and Production Handbook," The Ronald Press Company, New York, 1934.

dissatisfaction and discontent so prevalent, this plan is of little help to more efficient production.

The Halsey Premium Plan. This system is the pioneer of wage incentive plans, having appeared before scientific study of the amount of work a man could do was even proposed. It was originally based on estimated standards of time for doing a task.

This plan pays a worker hourly wages for actual time worked, and gives him a share of any savings he effects by doing his task in less time than the adopted standard. Not all the savings go to the worker, however, since it is reasoned that management makes possible the conditions by which the worker is able to produce in less than standard time, and hence should also come in for a share of the savings. Ordinarily, the worker gets one-third or one-half of the savings he effects,[18] leaving two-thirds or one-half, respectively, as management's share. The simple formula to compute a worker's earnings is as follows, assuming that he gets one-third of all savings:

$$E = R \cdot H_a + \tfrac{1}{3} \cdot R \cdot (H_s - H_a)$$

where $E =$ earnings; $R =$ hourly rate; $H_a =$ actual hours in which task is completed; $H_s =$ hours set as standard time required to do the job.

Under the Halsey system, the proportionate return for added effort will not be so high as by piece rate, but the worker is not penalized should he fail to produce in standard time. Since this system is not only an incentive to greater efficiency, but a plan in which workers feel more secure and management shares greatly in all savings made by workers, production costs are likely to benefit greatly.

Taylor Differential Piece Rate. This system was the first to recognize the necessity of determining accurately a standard or fair day's work. Under this system, a standard task or rate of production is determined, and two piece rates are set up. One of these rates is relatively low and applies to all workers who fail to produce a predetermined standard day's output; the other is relatively high and is paid to all who reach or surpass the standard output. This system was designed to eliminate poor workers by discouragingly low pay, and attract good ones by the opportunity to increase pay indefinitely. In comparison with the Halsey system, efficient workers do not share their

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[18] A system similar in formula to the Halsey system is the Bedeaux point plan, which sets up a standard of performance in terms of standard minutes, utilizing the "B" point, which designates the amount of work assigned to be done in 1 minute. The worker is paid for 75 per cent of the minutes he saves by working faster than the standard number of "B" points constituting a job.

savings with management, but receive full benefit of them. This system is applicable only where processes and methods are highly standardized, and guarantees no minimum or day wage.

Gantt Task and Bonus System. The Gantt plan recognizes the fallacy of penalizing workers for inability to attain a standard output or do a task in standard time. This system gives the workman a bonus (33⅓ per cent is a common figure) if he attains or exceeds standard, and guarantees him his day rate if he fails. On the basis of a 33⅓ per cent premium, the mathematical expression of earnings by the Gantt system, provided that standard output is attained, is:

$$E = 1\tfrac{1}{3} \cdot R \cdot H_s$$

or, expressed in terms of pieces

$$E = 1\tfrac{1}{3} \cdot R_p \cdot N$$

where R_p = rate per piece, N = pieces produced, and the other symbols are the same as for the Halsey formula.

The workers who fail to attain standard output under the Gantt plan are paid on a day rate.

The Gantt plan has merit in that it eliminates any penalizing of workers, hence making them feel more secure and better satisfied, as well as providing a goodly reward for any added effort above standard. Both the Taylor and Gantt systems operate on the idea that output can be stimulated greatly by giving the employee good working conditions and teaching him economical and efficient procedure.

The Rowan Premium Plan. This is but a modification of the Halsey plan, differing in that the premium is not a fixed fraction of time saved but is equal to the percentage of time saved multiplied by the amount earned on straight hourly rate for the job. Mathematically, this becomes:

$$E = R \cdot H_a + \frac{H_s - H_a}{H_s} \cdot R \cdot H_a$$

which, for the sake of convenience in calculating, can be reduced to:

$$E = R \cdot H_a \cdot \left(\frac{2H_s - H_a}{H_s}\right)$$

where the symbols are the same as for the Halsey formula.

This system offers greater incentive than the Halsey Premium Plan for small savings in time.

By no means are these all the available wage payment systems, for new ones are continually being developed. Once a system is established in a plant, there is a tendency, too, for it to acquire minor modifications to suit the specific conditions. Figure 1 shows graphically the

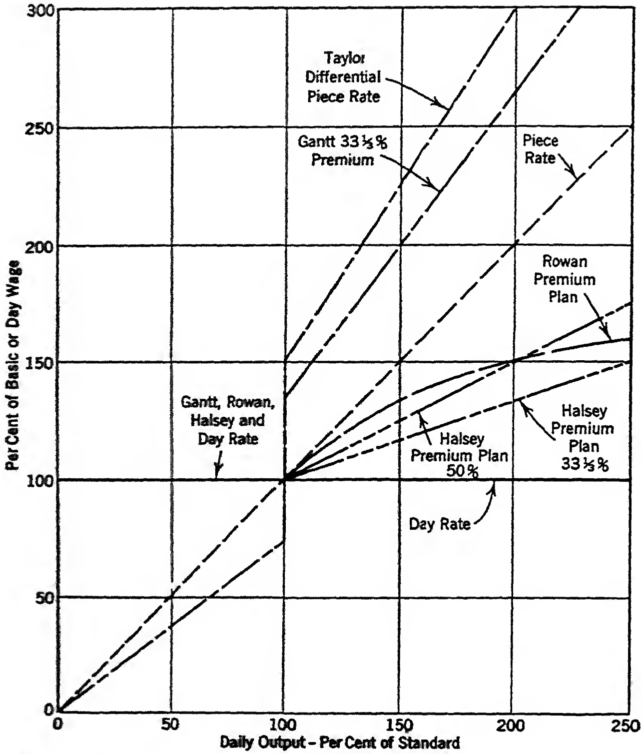

FIGURE 1. Graphical comparison of wage payment systems.

results of the systems we have discussed. For comparative purposes, the standard output for each system is taken as the same. Ordinarily, however, the Rowan and Halsey systems set lower standards at which premiums begin than the Gantt or Taylor systems.

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PROFIT-SHARING PLANS

Profit-sharing plans should not be confused with incentive wage payment plans. Profit sharing consists of distributing a percentage of a company's profits in a determined ratio at fixed intervals of time to employees eligible by service to receive them. In the wage system, the worker receives his premium every pay day, but in a profit-sharing plan, the distribution of profits is at longer intervals. Profit-sharing, contrasted to incentive wage systems, is not based on individual skill or initiative, and the lazy employee shares equally with the diligent one.

Most profit-sharing plans are complex and difficult for the average worker to understand, but nevertheless, they establish in the minds of employees an interest in earnings and in the value of eliminating waste.

"I Believe in Profit Sharing," an interview of Sen. Arthur H. Vandenburg, *Factory Management and Maintenance,* February, 1939, p. 38.

"What the Profit-Sharing Record Shows," *Factory Management and Maintenance,* February, 1939, p. 40.

"How Industry Looks at Profit Sharing," *Factory Management and Maintenance,* February, 1939, p. 41.

"Six Successful Profit Sharing Plans," *Factory Management and Maintenance,* February, 1939, p. 43.

REAL WAGES[19]

In studying wages, we should not lose sight of the purchasing power of the dollar. Wages may increase, yet the worker may not receive more than he did if the price of that which he purchases has increased a like amount. Furthermore, with an increase in standards of living, the wage earner presumably has a greater variety of needs. Popular opinion favors higher wages, both to increase the standard of living, and upon the theory that the ability to buy on the part of a large share of the population, in itself, supports employment. Too rapid an increase, however, in the wage scale creates a tendency to upset industrial progress and thus decrease employment and the total wages paid workers.

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wages are defined as the purchasing power of money wages.

The trend since 1914 has been toward higher real wages, and consequently a bettered standard of living for the worker. Probably this has been largely due to increased industrial productivity, as well as to a larger share of the total product going to the worker. Industry is coming to realize that workers constitute a large proportion of the total consuming public, when they are given purchasing power through higher real wages. It is to the advantage of industry, then, to see that this purchasing power is maintained.

Some companies advocate adjustment of workers' wages according to an index of the purchasing power of the dollar. This scheme is a fair one to the worker and one which should, if widely adopted, result in a more stable business trend through maintenance of purchasing power. Certainly it guarantees the worker a greater security in his assumed standard of living.

PRODUCTION OF A CONSTRUCTION PROJECT

As we leave manufacture, and turn briefly to a construction project such as the erection of a bridge or a building, we find the same economic principles involved, but they vary in importance. Here we are usually faced with the manufacture of a single structure at a given location, in the most economical way. As in the factory, we deal with materials themselves, labor required for transporting and fabricating materials, sequence of operations, and time of completion. Economy in erecting the structure leads the producer, who in this instance is the engineering or contracting firm, into a careful consideration of the advantages and relative costs of factory-built parts, either standardized or specially built, *versus* the actual fabrication of these parts at the point where the structure is erected. Thus, in the erection of a steel bridge over a stream, the maximum amount of fabrication of steel members will be done more efficiently at the steel factory, using standardized beams and plates, the only limitation being ease and cost of transportation.[20] In the erection of an office building, every effort will be made to use factory-built hardware and window frames. In building houses, the use of factory-built parts has steadily increased, and we are gradually approaching the time when, for smaller dwellings, the amount of labor in fabrication and erection that takes place at the location will be only nominal, as to cost and erection time.

[20] Pipe 30 ft. in diameter was required in building Boulder Dam. Since no railroad could transport such pipes because of insufficient clearances, a complete pipe-casting factory had to be erected at the site of the dam to make the pipes on location.

CHAPTER XII

PROBLEMS OF THE SUPPLIER—PURCHASING

We have already observed that the industrial organizations engaged in production, construction, and the furnishing of various forms of service have, over the years, become more highly specialized in their activities. One result of this specialization is an increased dependency of one operating unit upon another for a supply of products and services.[1]

As completed products become more highly specialized and also more highly developed, a greater variety of materials and semi-finished elements becomes necessary in their manufacture and construction. One has only to examine the automobile, modern power station, radio receiving set, or set of golf clubs, and trace to the origin every part, to see that each one of these requires a wide variety of materials and semi-finished elements. Likewise, one has only to observe the construction of a modern highway to see that, in building it, not only a wide variety of materials is used, but also a constantly increasing variety of tools is employed in its construction. The large railroad systems of today buy an ever-expanding variety of products taken from almost every line of industrial activity.[2] What one producer, therefore, purchases from another supports our constantly expanding industrial market. No one producer can proceed alone, for each is dependent upon others as suppliers and also as customers. All products are tied together by a complicated and intimate relationship, involving both buying and selling, to the end that the ultimate user is furnished a completely finished article or form of service. From this viewpoint then, we can gain some conception of the fact that selecting and obtaining those elements required in production constitute a very complex function—that of purchasing.

Purchasing is distinctly an economic function. Products wisely bought for a given purpose have an increased value, and the methods

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[1] Reference: "A Case in Industrial Economics from Republic Steel," L. C. Morrow, *Factory Management and Maintenance*, April, 1938, p. 45.

[2] The purchases of Class I railroads of this country are listed in Chapter XIII, page 327. It is interesting to note their quantity and variety.

followed in purchasing can contribute liberally to the success of an enterprise, or can ruin it.

THE VIEWPOINT OF PURCHASING

One is inclined to view buying and selling as two separate functions, the nature of which depends upon the particular transaction and whether the viewpoint is that of a buyer or seller. In our personal affairs, it is common for us to consider the selling function as a task which perhaps involves distasteful effort, whereas buying is usually considered a pleasant duty. Many of those who are engaged in commercial sales work expending their entire effort to obtain orders are tempted to believe that buying is an easy and simple matter. Often they wish that they might have a chance to buy instead of sell, because they feel that in doing so they would have the upper hand and a chance to dictate to others rather than being dictated to by those who buy. Such a conception is misleading, for, as we shall see, the duties of purchasing are neither simple nor easy, for intelligent and successful buying involves great responsibility requiring knowledge, judgment, and continued vigilance.

PURCHASING IS A DISTRIBUTION FUNCTION

Purchasing and selling are both a part of distribution. Obviously, economic units must do both, unless they are organized to perform only one function or the other as an agency for a second party. The true conception of any organization which provides products includes the obtaining of goods in some form and the addition of values consisting of ideas and labor which change the form of the goods, and ends with furnishing a product which performs a useful service. Thus, buying must come first, but it cannot be continued unless the particular producer sells that which he buys and alters in form to increase its value. We can imagine industry, then, as consisting of a large number of economic units which produce a variety of products or services in various degrees of ultimate completion, from the basic raw materials to the ultimate finished products, all tied together by a distribution relationship which we call buying and selling. Any individual transaction is both a purchase and a sale. The name applied to the transaction depends only on the viewpoint and position of one of the two transacting the deal—whether the flow of goods is to him or from him. No transaction can be considered successful unless both economic units are ultimately benefited. No transaction, either, is successfully completed until all the steps in the transaction are taken, ending with

the payment of funds and the ultimate satisfaction of both the purchaser and the supplier.

WHAT IS THE SCOPE OF PURCHASING?

In the broadest conception of purchasing, we might consider this to enter into all activities of the economic unit. The company buys or hires lands, buildings, machinery, the services of management, capital, labor in a great variety, transportation service, insurance, and so on. Purchasing, as we specifically term it, applies, however, to the buying of materials in raw or finished form. If we classify these materials as to their general use we find that they may be grouped as follows, for the average producer of technical products:

1. Goods required to form a part of the product itself, usually raw materials or semi-finished goods.
2. Goods required to accomplish manufacture, largely machinery and equipment.
3. Goods required to provide facilities under which manufacturing conditions exist.

We can illustrate these three points nicely by taking a particular example, say a builder of agricultural machinery. Such a manufacturer will require some form of purchasing organization which will be able to buy the steel, iron, brass, paint, ball bearings, tires, and perhaps gas or Diesel engines that form a part of the equipment this company builds.

This purchasing organization will also have to buy the shears, presses, lathes, conveyors, trucks, and electrical apparatus required for the production layouts.

Purchases must also be made, perhaps, of cement, steel, and lumber for repair and maintenance of the buildings or apparatus to provide a new heating and ventilating system which may be badly needed, or, again, paper towels, envelopes, carpets, and a host of miscellaneous equipment and supply items.

We see, then, that purchasing covers a wide variety of products used in operating the modern production unit.[3] Often this variety in the case of a large company covers almost the entire gamut of human needs, for this company requires a food supply, if it maintains its own restaurant for its employees; clothing for its uniformed watchmen and

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[3] Reference: "Materials from 1400 Suppliers—Their Selection and Control," *American Machinist*, May 20, 1936, p. 412.

attendants; medical supplies for its factory hospital; or even athletic equipment for its baseball team.

The purpose of those charged with purchasing consists of buying a service represented wholly or in part by the best and most suitable products for the least outlay in funds, with due regard to ultimate as well as immediate values. As we proceed we will see that many more factors are involved than simply those pertaining to the product itself.

Reference

E. B. Stockmann, "Purchasing an Important Duty of Utility Management," *Gas Age-Record and Natural Gas*, December 12, 1936, pp. 637, 660; January 7, 1937, pp. 31, 40; February 4, 1937, pp. 33, 40, 42. This subject is viewed from the public utility standpoint or from the standpoint of a producer of a technical service. The first series gives the general aspects and scope of purchasing; the second, setting up and organizing of the purchasing department and its personnel; and the third consists of general problems of purchasing policy.

RELATIONSHIP OF PURCHASING TO OTHER COMPANY ACTIVITIES

It will be readily seen that those delegated to perform the purchasing function must have close working relationships with those who design, produce, finance, sell, maintain, and use the products made.

The design and engineering departments must be consulted and their welfare guarded by the purchasing department by seeing that they are given good and proper materials for their designs. Likewise, close touch with design and engineering departments will prevent accumulation of unnecessarily large stocks,[4] as well as cure many of the other ills that sometimes arise when purchasing and design are not in accord. Of equal importance is cooperation with all manufacturing sections if inventories are to be closely watched and supplies of the right kind provided when and where they are needed. Oftentimes, by conferring with the shop or manufacturing sections, disposition can

[4] One company, in making its annual inventory, found that it had twenty times as many screw machine parts in stock as necessary. Investigation disclosed that the design of a machine had been changed, making fewer such parts necessary. The purchasing department had failed to work closely with the engineering department or this would not have happened. A perpetual inventory plan would also have shown this condition to exist.

Another company adopted a new alloy to overcome some of its troubles in manufacturing a cast part for the machines it makes. The purchasing department went ahead buying on its old schedules, unaware of the change in material, until the company found itself with a large stock of brass which had to be disposed of at a loss. This could have been prevented by cooperation.

be made of overstocked material, which will result in a saving where otherwise a heavy loss might be incurred.[5]

Purchasing and sales, it would seem, are quite opposite in function, and yet there is a great need for cooperation between these two. Although the merits of reciprocity in buying[6] are debatable, it is being practiced, and to practice it properly so that it may aid instead of hinder sales, requires the closest of cooperation between the sales and purchasing departments of a company. Many other considerations indicate the need of such cooperation. For instance, one purchasing department ordered a piece of equipment from a supplier at the request of the sales department. The sales department failed to tell the purchasing department that this would be shipped without unpacking to a South American customer along with manufactured apparatus. The purchasing department hence was unaware of the need of specifying export packing to its supplier, and a loss resulted in transit.

Failure to cooperate with the financial departments can result in just as unnecessary a loss as lack of cooperation with any of the other departments of a producing unit. Investigation can often disclose the financial position of the supplier and his ability to carry out a purchasing contract.[7]

By no means have all the reasons for a purchasing department to cooperate with all other company departments been cited, but those given are representative of why such cooperation is vital. The evils of lack of this spirit are very pronounced, and it is not difficult to single out a company whose purchasing department is trying to play a lone hand with no thought of or investigation into other company activities.

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[5] One purchasing department found itself overstocked with material of a certain size. Thorough cooperation with the shop sections, however, solved the problem, for, at only a slight manufacturing cost, the materials could be trimmed down and used.

[6] One disturbing factor that often enters into the operation of purchasing, as well as selling, is that relating to reciprocal trade. The supplier, being also a purchaser, may attempt to use this condition to further his position with little regard to the quality of products or service supplied. Any force at work which handicaps those charged with the duties of purchasing in obtaining the maximum in products or services for the outlay involved will in time prove destructive and uneconomical.

[7] One manufacturer's purchasing department ordered a special machine for its factory from a manufacturer without looking into his financial condition. Actually, the manufacturer was in dire financial straits and failed to complete the order. The result of this failure to confer with the financial department before placing the order was a great loss, due to the delay in waiting for another manufacturer to enter and complete the order for the machine.

"Reciprocity Buying," *Printers' Ink*, July 1, 1937, p. 37.

HOWARD T. LEWIS, "The Present Status of Reciprocity as a Sales Policy," *Harvard Business Review*, Vol. XVI, No. 3, Spring Number 1938, p. 299.

CAMERON MCPHERSON, "The Other Side of Reciprocity," *American Business*, May, 1936, p. 24.

THE PURCHASING ORGANIZATION

There are two main problems in connection with the organization of the purchasing department. The first is the internal organization of the department itself; the second is the relation of the purchasing department to other departments or divisions of the company.

We have already discussed the second problem to some degree. We have shown how the purchasing department, if it is a good one, functions on the same level as the departments of engineering, sales, and manufacturing. We know that the engineering department makes itself felt in the writing of purchase specifications and in suggestions of an engineering nature. Similarly, the manufacturing department has its say in ordering materials and machines, and the sales department might enter into the picture where reciprocal relations are involved. Thus, we may conclude that, although the purchasing department must maintain itself as a separate entity so far as commercial policies and the actual mechanics of purchasing are concerned, it still must regard itself as on an equal plane with the other divisions and accept their counsel.

In many large concerns, the purchasing department is headed by a vice-president or a manager in charge of purchasing. He is of the same standing as the vice-president in charge of engineering, sales, or manufacture, all of whom report to the president or general manager. In other concerns, the purchasing department is in a more subordinate position, and reports to the works manager or vice-president in charge of manufacturing. Whatever its position in the company's structure, modern purchasing is made sufficiently independent of the other functions to insure its operating at greatest efficiency.

The controversy that still exists, particularly among the larger industrial concerns, revolves around the degree of centralization that is desirable in a purchasing department.[8] The advocates of a decentral-

[8] Consider a large manufacturer that has four plants at different localities, and management headquarters at a fifth point located in a large city. Should the direct purchasing responsibility be located at the headquarters, or should each plant have its own purchasing department for those products required at each plant?

ized purchasing department advance the following arguments to support their claims:

1. The average individual charged with the responsibility of purchasing, it is claimed, lacks the necessary skill and training to administer a centralized department.
2. The average individual charged with the responsibility of purchasing, it is claimed, lacks sufficient knowledge to buy intelligently the large variety of products required by a group of manufacturing plants.
3. With the purchasing function exercised locally, quicker and more direct action can be attained in buying.

These reasons, we may admit, do carry a certain validity, but there are arguments just as good, or better, which favor centralization of purchasing at one point. They are:

1. The responsibility is clearly fixed at one point and in the hands of one individual and his associates.
2. With purchasing done at one point, those in charge can more easily follow business trends, price fluctuations, and their application to buying.
3. It establishes a uniformity in buying that is difficult when the department is decentralized.
4. It makes possible the economies of buying in larger quantities, since the requirements of the many departments and plants can be lumped into large orders.

It should be pointed out that, although a strongly centralized purchasing department has been found better in many concerns, some of the larger companies with far-flung plants have found it desirable to place a local purchasing agent in each plant in order best to meet local needs, with a general purchasing agent [9] at headquarters, to establish the policies and coordinate the activities of the scattered purchasing departments.

Broadly speaking, the functions of purchasing consist of these fundamental detailed activities:

Identifying an existing need for a product or service.
Defining this need in qualitative and quantitative terms.
Defining where and when the product or service must be furnished.

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[9] The term "purchasing agent" has been handed down from the time when purchasing was considered a highly specialized function entirely separate from other functions, and was often performed through agencies hired for the purpose. The term is still generally used to designate the individual charged with the responsibility of buying.

Determining where and from whom[10] the product or service can be obtained.

Placing orders—following them.

Obtaining proof that what is supplied meets the specified requirements.

Approving the payment of funds for orders filled.

REFERENCE

"Purchasing and the Purchasing Agent," *Mill and Factory*, July, 1937, p. 59.

OPERATION OF PURCHASING ORGANIZATION—STEPS IN PURCHASING

In studying the steps in purchasing, we will consider the methods employed today by those concerns which have developed modern methods for buying. The actual steps have been reduced, over a period of years, to a rather definite routine, which may be described as follows, as applied to a manufacturer of technical products:

1. Logically enough, the first step is to establish the need for making a purchase. This need may come as a request from those responsible for manufacture, or those responsible for the design of the product produced, or, again, from the purchasing department itself, to provide a replenishment of a depleted store of materials regularly used, the nature of which has become standardized.

2. Once the need is established, definite purchase specifications must be drawn up. These may be prepared by engineering talent located in the purchasing department itself, or similar talent in the ranks of those who design the product, or the two working together. In any event, the purchasing department must make use of its commercial experience in drawing up the specifications in their final form, and must pay heed to the recommendations of both manufacturing and engineering departments.

3. The specifications must be issued to prospective suppliers, and offers solicited. The suppliers may discover ambiguities in the specifications, and request an interpretation from the purchasing department, so as to ascertain exactly what is wanted, and such matters must be set straight.

4. When all bids have been received, the purchasing department then analyzes them carefully to see that they comply with specifications. The low bidder is determined, and his proposal compared with those of his competitors.

5. A contract or order is next awarded. Usually, the award is made to the lowest bidder who meets the specifications, although other con-

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[10] Reference: "Selecting the Source of Supply," Robert C. Kelley, *Executives Service Bulletin, Metropolitan Insurance Company,* February, 1938, p. 5.

siderations may enter in to influence the award, such as the reputation of the supplier in his ability to meet all commitments.

6. The purchasing department cannot rest once the award has been made. It must *follow up* the order and make certain that the goods will be shipped on time. If delivery is of great importance, a penalty clause may be inserted in the order to force the supplier to pay damages for each day's delay over the specified time of delivery.

7. Upon receipt of the material, it is usually a duty of the purchasing department to inspect the shipment and either approve or reject it. Approved material is assigned to the storeroom or put into immediate use, and rejected material is returned to the supplier.

8–9. The two steps remaining before the purchasing department can consider a transaction completed are the approval of the invoice, and the setting up of a record of the purchase for the purchasing department's files. These records may be quite valuable, both for checking back on the supplier, should the material later prove defective when used, and as a part of the purchasing department's statistics for future reference.

INTERNAL ORGANIZATION OF THE PURCHASING DEPARTMENT

When it comes to the internal organization of the purchasing department, specific statements are useless, since much depends on the size and type of company. However, the charts on pages 304, 305, and 306 will give an idea of the variety of organizations that may be found among the large and small industrial concerns.

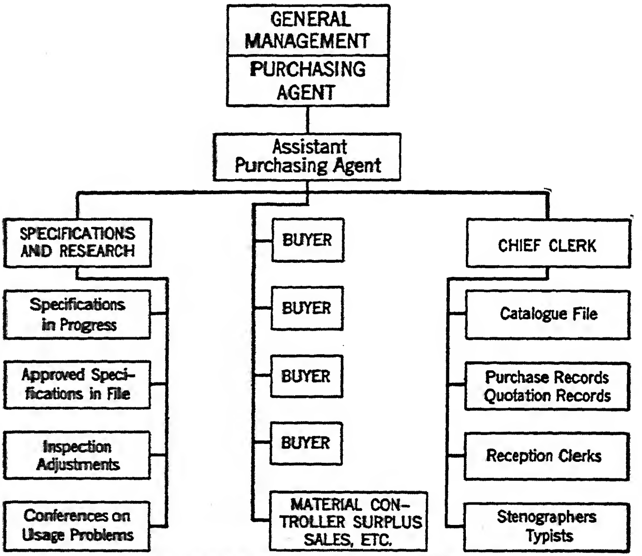
PURCHASING DEPARTMENT METHODS AND OPERATION

In many completed products, purchased materials and parts may constitute more than 60 per cent of the total manufacturing cost. Labor costs may be 15 per cent, overhead taking up the remaining 25 per cent. One would naturally assume that the cost of materials, then, would, first of all, be given scientific consideration and treatment. Such is often far from the facts, however, and only in recent years, and in those plants that are more intelligently managed, has purchasing been given exhaustive consideration and new and efficient methods put into operation. In many concerns, even today, the purchasing function is carried on much as it was thirty years ago, in an inefficient and unsystematic manner.

Why the purchasing department has often failed to yield to the onslaught of scientific methods is difficult to understand. Reasons why it *should so yield* are many, however. First, and most important, is the matter of dollars and cents expenditure involved. Since purchased materials constitute such a large part of the industrial budget, a few

per cent saved in buying will be reflected in a very large increase in the percentage of profits. Other reasons include simplicity of scientific purchasing, the ease of installing a modern system, and the relatively quick response of the manufacturing budget to scientific buying.

Typical of the old order of purchasing is the old-time purchasing agent who may yet be found in some concerns. He was traditionally



Purchasing Department of a Small Company with a Centralized Purchasing Department - All Purchases Made at Headquarters.

FIGURE 1. Internal organization of a purchasing department. From the prize-winning paper on "Measuring the Efficiency of the Purchasing Department" in a contest conducted by the National Association of Purchasing Agents.

"hard-boiled" and a "haggler."[11] He had little training other than that he picked up in the school of experience, and this was gained from mistakes made at his company's expense. His skill in purchasing was demonstrated by his ability to play two or more salesmen against one another, and thus beat down their prices as much as he could. He gave little or no thought to the future relationships with suppliers, and each purchase he considered a closed transaction. Some

[11] An interesting account of the haggling type of purchasing agent, the inefficiencies of his department, and the way one company solved the situation, is ...ined in "Pin Straightening Purchasing Agents," *American Business*, Febru-
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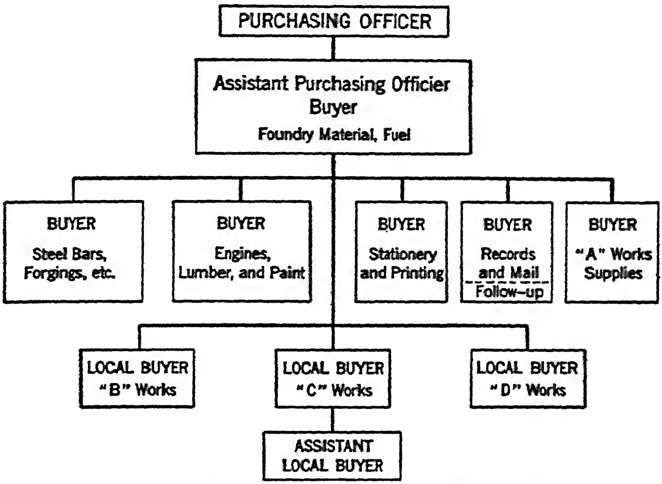
such purchasing agents even took particular delight in terrifying all salesmen who visited them.

Much progress has been made, however, and the modern purchasing agent presents a contrast to the type of individual just described. A modern purchasing agent of technical products usually has an engineering background. He is considered an executive, and he looks upon the purchasing function as a science where guesswork is reduced to a minimum. He thinks in terms of sound policies and business



Centralized Purchasing Department – But with Local Buyers Established at each Plant for the Purchase of Local Plant Requirements.

FIGURE 2. Internal organization of a purchasing department. From "Industrial Purchasing," Howard T. Lewis, Prentice-Hall, Inc., New York, 1937, Exhibit V, p. 67.

trends, instead of putting all his energies into saving a few dollars on an individual purchase. He realizes that his suppliers are necessary to the life of his own company, and that they are entitled to a fair profit; thus he is willing to pay a fair price in order that they, too, may stay in business and furnish products of quality. The modern purchasing agent recognizes that sales engineers may be valuable in helping him with a solution of his problems, and in keeping him abreast of new developments;[12] hence he treats each visiting sales

[12] Sometimes a purchasing agent feels he is being helped so much in his buying that he is being *told what to buy*. An interesting article asserting this, followed by a refuting of the charges, is found in "P. A. Pleads for Peace," by W. G. Morse, and "Peace Indeed! But Let's Face the Facts," by W. A. McDermid, *Printers' Ink Monthly*, February, 1937, p. 13.

engineer with courtesy, fairness, and in a businesslike manner. He knows much about the economics[13] of the products he purchases, and he consults market statistics as often as his suppliers' price forms.

We have dwelt largely on the primary function of a purchasing department, which consists of placing orders. However, besides this, the department must know *when* and *what* to buy. This cannot be done by "intuition" or guesswork. It requires an intensive study of

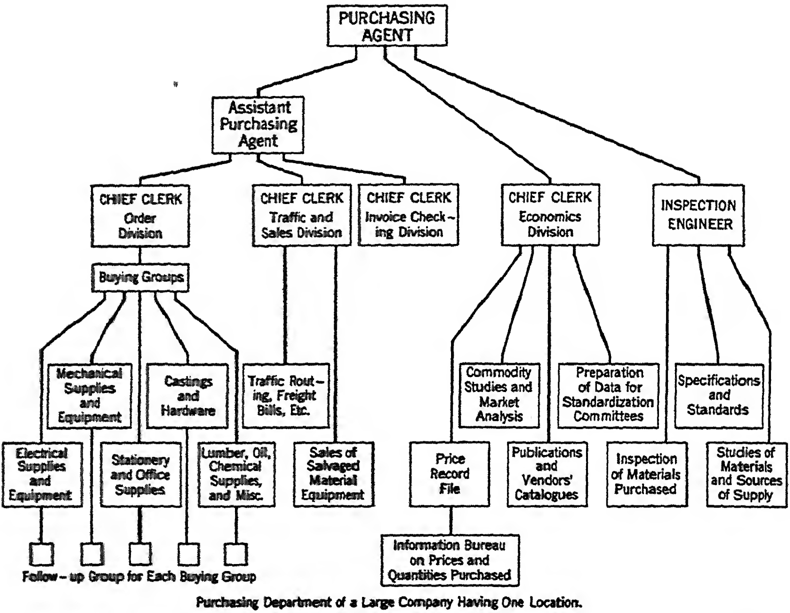


FIGURE 3. Internal organization of a purchasing department. From "Handbook of Business Administration," W. J. Donald, Editor-in-Chief, McGraw-Hill Book Co., Inc., New York, 1931, Chapter XII, "Purchasing," by E. T. Gushee and F. A. Compton, p. 708.

price trends and business conditions, and the volume to be purchased at one time will be governed by analysis of these statistics. It is universally recognized that business follows a "cycle" of progress. To those skilled in interpreting the state of business activity, it is frequently possible to determine with reasonable accuracy whether we are headed for a period of "recovery," "prosperity," or "depression." The determination of buying policies in such periods depends upon the purchasing agent's analysis of business trends from available statistics.

[13] Reference: "Economics and the Purchasing Agent," D. H. Lyons, *Iron Age*, March 3, 1938, p. 54.

Still another important duty of the modern purchasing department lies in the standardization of specifications and materials. By setting up a standard form for specifications, work may be greatly lessened and expenses materially reduced. In a company with many plants in various locations, additional savings are often made by setting standard material specifications for the entire organization, and by lumping purchases to secure greater quantity discounts.

In writing specifications, the purchasing agent strives to meet the following points:

1. The specifications must be worded as clearly and as simply as possible.
2. The specifications must be accurate to a degree that eliminates danger of misinterpretation and forestalls evasion on the part of the supplier.
3. The specifications should comply with standard forms of recognized and nationally known bodies, such as the United States Department of Commerce.
4. The material specified should, if possible, comply with nationally known standards.
5. The specification must describe the material and the performance requirements which it is to meet. It should, in fairness to the supplier, describe the inspection and tests to which the material will be subjected.

A purchasing department, to function efficiently, must keep adequate records. These consist of data regarding:

1. *Previous purchases:* Price paid, delivery on time or delayed, condition when received, test records and inspection record, and performance under machining or producing operations.
2. *Suppliers:* This file gives a complete picture of the available sources, their reputation and previous record of performance.
3. *Materials:* These data give immediate reference to prices, suppliers, previous purchases, and performance.

With a catalogued file of these data available, the work of the purchasing agent will be greatly facilitated, for he can refer to a material, a supplier, or a previous transaction. However, too many detailed records are cumbersome and fail to pay their way, but too few records offer a severe handicap.

Some question still exists as to the relationship between the purchasing and inspection departments. Some companies maintain that the two must be kept separate in order to maintain the integrity of both; other concerns make the inspection division subordinate to the purchasing department. There is much to be said for the second

method, since the inspection and test of incoming materials are definitely allied to the purchasing function itself. The checking of materials against the purchasing department's specifications can usually be more readily performed by the purchasing department's own inspectors. Some favor keeping the two functions separate for the purpose of having one as a check against the other. Though this may be satisfactory in some instances, it may also cause friction in others.

The modern purchasing department considers many factors when it determines "how much" of anything to buy. It considers the interest on the money to be tied up in stocks, depreciation, and storage charges. Such factors indicate the advisability of carrying stocks which are not excessively large. General price levels and trends and yearly consumption are other points to consider.

References

T. F. Smiley, "If the Purchasing Agent Slips—Then You Hear About Him," *Oil & Gas Journal*, May 19, 1938, p. 62.

Carleton Reynell, "Modern Purchasing," *Society for the Advancement of Management Journal*, July, 1937, p. 118.

Howard T. Louis, "Standards of Purchasing Performance," *Harvard Business Review*, Vol. XIV, No. 1, p. 480.

CHAPTER XIII

THE MARKET FOR TECHNICAL PRODUCTS

THE DEMAND FOR TECHNICAL PRODUCTS

In no other country than the United States of America is the demand for technical products and services so large. There appear to be some very definite reasons for this fact, and they may be summarized thus:

(*a*) We have already pointed out the fact that the American pioneering spirit has within the last few decades been concentrated upon invention and the development and production of technical products to the end that new and useful products have been offered to the public.

(*b*) The American mind interests itself in things that are new, and is willing to try them.[1] "Having the latest" of everything appears to attract most of us and satisfies our pride.

(*c*) With the steady advance in this country of the wage scale, the average person not only desires labor-saving devices, but also is able to purchase them.

(*d*) The lack of class distinction socially creates no barrier to the purchase and sale of products. The automobile, which in its earlier days was a luxury used by the rich and fashionable, was adopted by all, as soon as it proved reliable and the price became reasonable.

(*e*) The American people not only are free to spend, but also accept readily the plan of "pay as you go" buying.

(*f*) Mass production and standardization not only have resulted in technical products being produced in great volume, but also have added to their reliability and made low-priced and convenient servicing possible.

(*g*) Living standards in this country have advanced almost uninterruptedly over a period of years so that the luxury of yesterday has become the necessity of today.

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[1] Consider the modern, streamline train. For some time, railroad men sought to check the decline of passenger revenue. Then, in the midst of a depression, someone conceived the idea of stainless-steel and aluminum trains which not only were fast, but luxurious and beautiful, too. The idea *took* with the public, and every new train has produced additional revenue and traffic. The manner in which the public accepted this new service is exemplified by the revenue record of a Western road's two transcontinental streamliners. The revenue from these trains, for the first five months of operation, was respectively \$8000; \$49,000; \$83,000; and \$101,000.

(h) In all branches of industry, technical products for purposes of production and maintenance have been welcomed as helping toward more efficient operations and a better quality of products built. There has been no legislation forbidding the use of so-called labor-saving equipment.

THE MARKET

When we speak of the "market" for a technical product, we do not refer to any particular place where this product is bought and sold, but rather to the existence of a demand for a product which may be met by a supplier. The market may have several qualifications, for it may be limited to certain places and areas or to certain classes of purchasers, and it may depend upon such factors as time and the availability of funds and the seasons of the year. For instance, there is a demand, or readiness to buy, and consequently a market for machine tool equipment at Detroit, Michigan, by automobile and automobile equipment manufacturers prior to the bringing out of new models of automobiles. At that time, there is a greater market than at other times, because plants are being re-equipped owing to changes required in productive layouts.

Any market exists, too, only where there are both a *willingness* and an *ability* to buy. A coal-mining company might be glad to mechanize its mine, recognizing that the cost of mining would be reduced thereby, but it might not have sufficient funds to do so.

Markets may exist for a given product, and yet be unrecognized. Vacuum cleaners first found their market for use in homes. Only later was it realized that they could be used for cleaning purposes in factories, in spite of the fact that for many years blower systems had been employed for removing waste materials such as sawdust and shavings.

Markets are being continually created for a product by creating the product itself. For instance, photoelectric tube equipment is now used in counting or sorting certain products manufactured, but this market did not exist until the photoelectric tube was developed. It is often difficult to determine which was the more active force in developing the market for a product—the insistent need for the product or the creation of the product or service followed by a cultivation in the recognition of its need.

We find *existing markets* which require little more to develop them than an availability of the product to the potential purchasers, or again we find *potential markets*, which require not only the availability of

the product but also its exploitation,[2] or the supplying of some condition which will enable the possible purchaser to buy. For instance, a city may need a new pumping plant to provide an adequate water supply, but the city cannot be said to be in the market for such equipment until funds have been made available through some plan of financing the purchase by taxation or the sale of bonds. In many instances, a potential market has changed to an existing market by offering the purchaser a time payment plan in which he can successfully participate.

There are in this country some twenty-five million farmers, many of whom could use electric current to advantage for furnishing light and power to their homes and farm processes. They are not potential purchasers for such items as electric lamps, appliances, and electrically operated machinery until some reliable source of electric power is made available to them at a reasonable cost. As soon as power is made available they become potential customers, but limited funds or other reasons may not permit the classification of all of them as constituting an existing market.

The strength of markets varies with the demand and amount of the supply. Just as in an air-filled bottle you may have pressure or a partial vacuum, so for a product you may have a "sellers' market" in which the supplier tends to dictate terms of sale, or you may have a "buyers' market" where the purchaser holds the upper hand.

In studying specific products and services and their uses, we find a vast interdependence in the demands of all industrial activity. The manufacturer depends upon a large variety of products built by other manufacturers and upon services rendered by those furnishing transportation, power, and communication. This is a resultant characteristic of our continually increasing tendency toward specialization of human effort. We find that the demand for products and services is largely *horizontal* or *vertical* in character. Products of *horizontal* de-

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[2] No more impressive a demonstration of product exploitation is to be found than is presented by a prominent roller bearing manufacturer. The company early advocated the application of anti-friction bearings to railway equipment, and first put them on coaches, where they were a huge success. Next, they were put on the trailer and engine trucks of locomotives and on tender trucks, but railway engineers refused even to experiment on their use as drive wheel bearings. The bearing engineers, to prove this was desirable, built a modern locomotive at a cost of $250,000, with tapered roller bearings on every wheel, and turned it over to the railroads for testing.

In two years, fourteen railroads tested this huge "sample," and one road liked it so well that it bought it outright. Since then, tapered roller bearings on locomotive drive wheels have saved large amounts in lubrication and maintenance for the railroads.

mand are usually of a standard sort and used in a wide variety of industries. They may be highly specialized in purpose, but find a wide variety of purchasers. Common examples are bolts and nuts, electric-light bulbs, typewriters, pumps, blowers, and industrial trucks. Common services such as the furnishing of transportation, power, and communication fall into this category. Products of *vertical* demand are usually more highly specialized and find a demand from one or a very few purchasing groups or industries. For instance, miners' lamps, bread-baking ovens, sugar centrifugals, knitting machines, and coal cutting machines are used only in particular industries and hence are correctly termed products of a *vertical* demand.

MARKET CHARACTERISTICS AFFECTING PRODUCT AND SERVICE

In Chapter VIII we studied the interests of the purchaser in various classes of technical products and services. Obviously these constitute a guide for the producer in creating products or services to meet a market. It is impossible to disconnect the characteristics of the product from the requirements of the market, and also the methods to be pursued in distribution, because, after all, purchasers support the market and their acceptability of the product and service determines largely the nature and characteristics of the product. Two forces are continually at work in the creation of markets; one is the development of new and improved products, and the other is the development of new and improved processes which, in industry, call for new products. A few examples will illustrate these forces and how they work.

For many years people have used locks, to protect person and property. Recently, especially as automobiles have come into general use, the lock has become still more common, and the embarrassment in losing a key has become an ordinary experience to many. This condition has created a demand for little shops in every community where in a few minutes one is able to obtain a duplicate key cheaply. A large market has thus been created for machines which will duplicate keys quickly.

Particularly in the South during the hot weather, people suffer from the heat during the day and also have difficulty in sleeping at night. This condition has always existed, but people have come to look to science for a solution of their problems in securing comfort. Recently, fan and blower manufacturers have perfected small electrically operated fans which exhaust the air from the attic and cause a refreshing breeze to come into the house from the windows during the night when the outside air is cooler than during the day. A large demand has developed for these fans, and a local technical service to take care of their proper installation and service has also been found necessary.

Automobile manufacturers, in search for a better finish for headlights and other bright parts upon the automobile, stimulated the development of the chrome-nickel plating process. As this became practical and popular for automobile parts, it became readily accepted for most highly finished articles such as plumbing fixtures and clocks.

X-ray equipment, first generally used in the medical field, has been altered somewhat and made available to manufacturers of cast products to detect flaws. Thus there has developed a limited market which formerly did not exist at all.

Early in the use of machine tools the demand for grinding machinery existed almost entirely for sharpening small tools. As production processes were perfected, closer limits were required and finer surfaces were found necessary, there grew a very large demand for grinding machines which took the place of cutting machines. What contributed largely to this transition was the improvement in grinding wheels themselves, which made them much more suitable for production operations.

Distributors have found that the purchaser is influenced favorably to a given product by obtaining it in a package or container which not only protects the product but also aids in the handling of it. Suppliers of the product have found, similarly, that packaging eliminates waste, simplifies packing, handling and storage, and provides an opportunity for advertising the name of the maker and the product. Consequently, there has been developed a large demand for all sorts of packaging machinery and equipment.[3]

Thus, we find new processes introduced and old processes changed, and with it all new markets are created.

MARKET ANALYSIS

Market analysis is the study of the present and future market for a given product. Its initial purpose is to find out the extent, location, volume, and nature of the market, with indications as to probable future trends. Market analysis is to the producer what the route map is to the automobile traveler, for it shows him the district over which he is to travel to reach the destination by the quickest and easiest route.

The ultimate purpose of market analysis is to guide the producer in reaching and serving the market in an adequate and economical manner, so that he will make a fair profit upon his product for the benefit of both those who own the business and all of its employees.

From our study of the variety of technical products and the variety of purchasers, we find that markets are quite complicated, for they

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[3] Reference: "Merchandising around New Metal Packages," by Oscar S. Tyson, *Industrial Marketing*, January, 1938, p. 20.

depend upon many conditions which exist but are not easily recognized. Markets are continually changing, and, unless the producer constantly studies them and alters both product and methods of distribution, he is quite likely to suffer loss of business and commercial position. A few examples of the changes and altering of product and distribution will serve to make this point clear; for instance:

> The manufacturers of office equipment such as tabulating, recording, duplicating, and calculating machines have enjoyed an increasing opportunity for business through the increased volume of records which business companies must maintain in view of more extensive and complicated records for government tax purposes. Unless these producers study what our taxing authorities require of business concerns, they are unable to supply satisfactory equipment where and at the time that it is most needed.
>
> The market for leather belts for transmitting power, so popular in all manufacturing industries for so long, has been relatively decreasing in recent years. Power-producing units have been, as a general rule, more commonly connected directly to the driven machines. Other forms of power transmission, such as gears and endless fabric belts, have come into common use. Certainly study of the market, with all its tendencies, is necessary to any manufacturer who is trying to keep pace with such a change in methods of transmission of power.
>
> Not many years ago steam engines were the common source of power, and were used almost universally by industry. Today, power is commonly produced by steam turbines or Diesel engines, and many of the manufacturers of steam engines have abandoned this activity and are now producing these other forms of power-producing units. This shows how vast a change may be necessary if a supplier expects to remain active in the supply of some technical product.
>
> A most interesting development in the market for pulp and paper-making machinery has occurred within the last few years. Owing to the development of improved processes in making paper from quick-growing pine in the Southern part of the United States, many large paper mills have been established in the South, where practically none existed before.

The *location* of the market is of first importance, for, without this knowledge, the producer is unable to direct distribution effort effectively and economically. The producer of electric refrigerators must know where the mass of population that lives in wired homes is located. Likewise, the manufacturer of jordens must know where the pulp and paper mills of the country are located since these represent his sole market.

Production can be guided and supported only by distribution;

therefore the producer must know how much of the kind of product that he makes the market will absorb, and what share of this market he can expect to obtain. *Volume* requirements depend upon a variety of factors, but a careful study of the market is the only method upon which to base dependable estimates. The following examples illustrate how the market must be studied, and the factors that must be taken into consideration when the manufacturer sets out to determine his volume requirements.

The manufacturer of contracting machinery, such as power shovels, concrete mixers, portable air compressors, trucks, and the like, will watch closely construction operations in the district he attempts to serve, and will, to a large extent, measure the market for his products by the extent of construction projects contemplated and about to be undertaken.

Manufacturers of coal-mining machinery will watch the condition of the coal industry very carefully. The demand and price of coal, together with labor rates, will largely determine the future demand for mining machines. On the other hand, when mining companies are unable to spend money for new machinery but still can maintain their operations, the demand for repair parts for existing machines may be large, since the mine operators will endeavor to keep up production with the least outlay for machinery and equipment.

Market analysis will show the *time* of the year when purchasers buy, and enable the producer to prepare to meet the demand.

Electric fans are bought almost entirely during the summer months. On the other hand, economical manufacture based upon mass production calls for continuous manufacture during the entire year with stock accumulation in the warehouse of the manufacturer and storerooms of jobbers and dealers. Knowing this seasonal demand, the manufacturer works closely with both jobbers and dealers so that electric fans are available for immediate delivery to ultimate purchasers as soon as the hot weather sets in.

An adequate study of the market furnishes the producer with many other market facts in addition to a knowledge of where the market is located, how much it will buy, and when it purchases. Many technical products are sold through distributors of various sorts. In the domestic field, household appliances are sold through specialty shops or department, house furnishing, or hardware stores. In the industrial field, equipment and supplies are sold direct or through manufacturers' agents, mill supply houses, contractors, or similar outlets. For a given product, what is the best method of distribution? The producer,

anxious to distribute effectively and economically, can determine this only by a detailed study of customer markets with due regard to buying habits.

In no industries is a greater knowledge of the market required than in those commonly classified as the public-service group. The interests which supply adequate and economical telephone, telegraph, and electric power service must know the kind and cost of service desired with all its ramifications, and also the extent to which it should be made available. This calls for a minute study of conditions surrounding population—its location, growth, and volume requirements. Large amounts of capital are necessary to furnish service facilities, and the facilities must be properly located with a view to present and probable future demand. Time is required to establish and provide operating locations and lines of communication, and capital is likely to be invested unwisely unless there is a complete knowledge of present—as well as probable future—conditions upon which to base plans.

The laying out of public works for water supply, flood prevention, sewage disposal, and street traffic requires the same degree of careful planning, all based upon the principles involved in market analysis.

For a manufacturer who contemplates producing an entirely new product, a study of the possible market is most essential, for success or failure may depend upon such studies.

There are many examples where market studies have been the direct cause of the development of other markets for a product which were not even thought of at the time of the initial analysis. The following is such an instance:

> Cellophane was placed upon the market only after exhaustive studies had been made of its possible use in one or two fields. As this product was used to wrap other products, a study of the market involved practical demonstrations that products wrapped in Cellophane had a greater acceptance than when unwrapped or wrapped with other materials. Before the product was offered for sale to several possible purchasers, its usefulness was proved so that its use was fully justified.
>
> The success of Cellophane, however, as a material with which to wrap certain articles, introduced a demand for new types of wrapping and packaging machines, for machines used for handling existing products were found unsuitable for the purpose.

From what has been said it is clear that, if the supplier is to furnish an acceptable product and reach a market adequately and economically, facts upon the market must be determined, evaluated, and placed in a usable form. Such studies guide the supplier in all his

major activities. We might say, as a summary, then, that, assuming a given product available for sale, the following factors are of most interest to the supplier:

General conditions of business. General business activity varies from year to year, and the demand for products varies to a greater or lesser degree, depending upon the nature of the product. Any supplier must follow the course and trend of general business activity, and study the relation between it and the demand for the particular product furnished.

Location of possible purchasers. A study of the geographical location of various buying units is necessary, and any trends which appear to govern a changed location of them.

Volume of purchasing power. A study of the volume demand of the varying buying units is essential, on which to base the extent of sales effort and production.

Price and quality. A study of the market and its changes in relation to the price and quality of the product furnished, serves as a basis for establishing correct selling prices and acceptable products.

Stability of demand. Whether the market for a given product is likely to continue is a matter of importance, or whether it will change with popular fancy, or with the availability of other and superior products. During the early history of radio reception, earphone sets were in great demand, but they fell into disuse as receiving sets were improved and the loud speaker was perfected.

Initial or replacement demand. Whether the product is to be largely sold to initial purchasers, or for replacement of existing inferior or worn-out units, will influence sales policies and plans.

Elasticity of demand. Sales management must know whether the demand can be increased by an improvement in the product itself, or by sales promotional effort, or through other planned devices of distribution.

Purchasing habits.[4] A study of the purchasing habits of customers, which will vary according to a wide variety of causes. Such studies show under what conditions and through what channels of distribution customers desire to obtain the product offered them. Customers may desire to purchase, for instance, on extended terms, or may require installation service. Many products, too, are bought in relation to other products, as starting and lighting batteries for use with automobiles. Purchasing habits are often firmly fixed, and though they appear illogical, cannot be altered by the supplier without great effort and expense.

Competition. A study of competitive products, and the methods of distribution and rendering of services, usually throws considerable light upon the market the supplier is attempting to meet.

[4] Reference: "Public Buying Habits Burden Industry with Idle-Day Costs to Provide Capacity for Peak Demands," Walter M. Dake, *Coal Age*, Novembe 1938, p. 35.

ELDRIDGE HAYNES, "Market Research Will Help You Sell More Goods *Now*," *Industrial Marketing*, June, 1938, p. 18.

E. J. KLOCK, "Market Research Aids Industrial Sales Promotion," *Mechanical Engineering*, April, 1937, p. 230.

DUDLEY W. WALTON, "Market Research in Engineering," *Engineer*, Vol. 164, July 2–August 6, 1937, p. 2. This article gives some excellent discussion on the various phases of market research.

"Market Research as a Guide in Selling and Advertising," *Industrial Marketing*, April, 1938, p. 12.

MARKET GROUPS

Technical products originally found their market for use in military activities, construction work—such as water and gas supply systems, and mining developments. As manufacturing, transportation, and communication developed, the demand widened. It began to invade the farm, office, store, shop, and home. Technical products, today, enter into every phase of our life, because our bodies are fed, washed, clothed, tempered, entertained, and transported by means of mechanized services.

In order to study the broad market which now exists, we can profitably divide it into five main groups. These groups show clearly the five main classes of sources from which markets are derived. They are:

1. From the individual purchaser who buys for his own use, principally for the home.
2. From commercial and institutional purchasers, such as offices, stores, shops, hospitals, theaters, and office buildings.
3. From agricultural enterprises.
4. From the large variety of industrial purchasers, including:
   - Manufacturing companies.
   - Mining and lumbering companies.
   - Construction enterprises.
   - Public-service companies.
5. From various governmental units.

We shall study somewhat briefly these groups in showing their importance in the creation of markets for technical products. Since the requirements of governmental units parallel closely those of industry, we will not dwell on this market.

The Market from the Home and Individual

The so-called "home" market for technical products consists largely of a demand for products which will save labor. Such products are now familiar to all of us, although not many years ago they were technical curiosities. Several of them may be considered a redesign of types which have been long in use; others are entirely new. The development of the small motor and electric heating element, together with the availability of electric power, has made the wide acceptance of many such appliances possible. The list of such appliances is constantly expanding, but the leading items are the vacuum cleaner, domestic washer and ironer, mechanical refrigerator, dish washer, electric sewing machine, automatic oil and coal burner, electric ventilator, radio receiving sets, electric winter heater and range—to which might be added air-conditioning units which will rapidly be included in our domestic heating and ventilation systems in the future.

To such a list might be added a large number of small devices or "gadgets" which are finding an increasing use in housekeeping, usually for convenience in the preparation of foods.

The mechanization of the home which has been taking place during recent years serves as a dramatic example of the results of combined engineering and merchandising skill. In one sense, the home can be looked upon as a factory for the production of comfort and happiness. As an enclosure, it requires illumination and the proper control and conditioning of air. Within the home, certain mechanical processes go on, principally relating to cleaning the fixtures and clothes we wear, and the preservation and preparation of food supplies.

Probably the most conspicuous example of a technical product sold in large quantities to the individual is the passenger automobile. Since it furnishes a form of service universally popular and necessary, and is independent of an external source of power, its development has opened the way for a large demand for other technical products such as those required in the building of highways and furnishing service locally to the automobile owner.

The acceptance of such products as these which are purchased largely by the individual, and particularly those purchased by women, is determined to a large extent by emotional appeal and the adaptation of the article to the personal habits of the individual, as previously pointed out.

Market studies, in connection with such items, to be useful must relate to the matter of individual taste as well as to utility. Thus,

sales promotional effort in reaching the market existing in the home and from the individual offers a large opportunity for the study of mass market psychology and the use of the various devices of sales promotion and advertising.

Elaborate market studies are continually being made of market demands for various technical products sold to individuals. For the most part, such studies are made by the manufacturers themselves, or those companies engaged in distribution and sales promotion. Most market studies relate to such factors as these:

> The *location* of possible purchasers, from which follows the *volume of demand* according to geographical areas. Such studies show the purchasing density of selling territories. For instance, in respect to electrical appliances used in the home, one measure of possible demand will be the number of wired homes. Other factors enter into this, however, depending upon the class of population considered. In mill towns, or in Southern cities where the negro population is large, the buying power will be lower than in suburban, residential districts.
>
> The *quality and price* requirements for the product will differ materially in different areas, depending on the varied classes of purchasers.
>
> The demand for the product will depend upon *local conditions* characteristic of the district. Air-conditioning and ventilating equipment will find its largest demand, other conditions being equal, in warm climates. Oil burners will find little demand where soft coal or natural gas are available at low prices, but, on the other hand, there will be a large demand for automatic stokers or gas furnaces. Electric ranges will be popular only where rates make it possible for electricity to compete with other forms of heat for cooking.
>
> The *purchasing habits* of the buyers are an important characteristic of the market. These may relate to the style of the product required, cash purchasing *vs.* installment buying, the class of retailer most effective for local distribution, seasonal demands, buying motives, and so on.
>
> The factors concerning *transportation costs*, methods of *packing and shipping*, and importance of *availability* to serve the market by local warehouse stocks, are all important in making market studies of this class of buyer.
>
> The products offered by competitors and their methods of distribution are essential to any complete market study, because much can be learned from them as to what to do or what not to do.

Various "yardsticks" have been tried to indicate the buying power of the individual, the most important being that based upon the family income, as shown in federal tax statistics.[5]

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[5] Reference: "Mechanical Refrigeration and Family Income," John Perry, *Selling*. June 23. 1937, p. 24.

The Market from Business and Institutional Purchasers

Technical products find a ready market in the field of business and institutions. Of increasing importance is the market created by the growing mechanization of public and semi-public buildings, stores, offices, and service establishments such as garages, repair shops of all sorts, laundries, shoe-repairing shops, bakeries, amusement houses and parks, and many others.

The use of technical products in business establishments and institutions has in the past proceeded more slowly than the adoption of similar products for domestic use. The wide use of such products by individuals themselves, in their own homes, has definitely had its influence in recent years in hastening mechanization in all business institutions employing people and catering to their demands. Competition and a greater appreciation of those elements which go toward customer satisfaction and employee comfort, happiness, and efficiency constitute the forces that are now leading to rapid mechanization in this field.

Air conditioning, for instance, is employed by a restaurant, and at once there is a large increase in the number of meals served. Such additional business is attracted from other eating places, and they must provide a similar service to regain patronage. Thus, the total volume of business done by restaurants may have increased only slightly, but all patrons are provided with greater comfort.

One office building, for instance, rehabilitates its interior. New elevators are installed, better forms of illumination are adopted and heating and ventilating systems are revamped. At once, vacant office space in the building becomes desirable and tenants are attracted from less desirable locations—with the net result that standards are improved and offices, in general, become better places in which to work.

Office appliances have, in recent years, been improved to a remarkable degree, and new kinds of recording, duplicating, tabulating, and calculating machines have been introduced. With the increased use of records of all sorts, this work could not be efficiently and accurately done today without them. Operators have become specialists in the various types of machines, and the manufacturers of these machines have themselves developed elaborate plans for training operators, as well as systems of keeping records—all of which constitutes a part of their distribution service.

Hospitals are depending more and more upon technical products for comfort of patients, efficient operation, and the general betterment of such institutions. Schools are being more highly mechanized in the

interest of greater efficiency and better conditions for the pupils and teachers. Even our prisons and other state and national institutions are looking to technical products for the improvement of general conditions and for increased efficiency of operation.

The need for a study of the market in this field of businesses and institutions is just as important—if not more so—than in the home,—because purchasing is done with a view to avoiding losses or increasing profits.

References

"Modern Hospital Uses Winter Air Conditioning in Operating Rooms," *Heating and Ventilating*, May, 1936, p. 32.

Donald P. Caverly, "Automatic Lighting Control Safeguards Children's Eyes," *Electrical World*, February 13, 1937, p. 542.

The Market from Agriculture

The market from agricultural activities, of interest to the engineer, deals largely with agricultural machinery and equipment used in the production, storage, and handling of farm products. Agricultural products, prior to consumption, become a part of the processing industries, such as those involved in the milling, meat, sugar and confectionery, dairy and ice cream, baking, canning, and bottling industries.

The market for farm implements for the cultivation of land and the gathering of crops will be touched upon only briefly. The design of such implements requires technical skill, but distribution is largely merchandising in nature, for, being complete self-contained units of equipment ready for operation, little is needed in the way of application of an engineering character. The market naturally exists in agricultural areas, and is quite variable, depending considerably upon seasons of the year and the volume and selling price of crops which determine the farmers' purchasing ability. Time payment buying is common, and sales risks are large in this field.

In contrast to farm implements, we find a large variety of fixed or semi-portable equipment on the farm which produces or processes a great many farm products, such as dairy machinery, pumping equipment, incubators, feed grinders, as well as household appliances. With the constant extension of electric power lines in farming districts, and the introduction and improvement in a wide variety of electrically driven apparatus, the acceptance of which is continually stimulated by the scarcity and high price of farm help, we find that mechanization of the farm is a relatively new and attractive field for engineering skill. Manufacturers of equipment, public utility companies, and farm

associations have joined hands in a study of the economic problems existing in farm mechanization.

References

"Agriculture," *Iron Age,* January 7, 1937, p. 104. An excellent insight into rural mechanization.

Harry G. Davis, "Farm Mechanization Has Changed the Life of the Entire World," *Automotive Industries,* February 13, 1937, p. 219.

W. R. Woolrich, "Process Industries and Rural Stability," *Mechanical Engineering,* July, 1936, p. 427.

The Market from Industry

In studying the market which the various industries offer to the manufacturer of technical products, we find a rather bewildering variety of classes of purchasers, and also variety of products purchased.

As industry has progressed along the path of specialization, two opposite tendencies have appeared. One is for the manufacturer to make, rather than purchase, those elements which he requires. This has been particularly true as organizations have grown to mammoth size and as their requirements for duplicate parts or completed elements have increased. Automobile manufacturers now build almost every part of the car, such as gears, axles, engines, and wheels, whereas formerly these were purchased from independent manufacturers. Only where the nature of the part differs widely from their line of work and where the part is required as a popular replacement, as with tires and batteries, is the practice uncommon. The automobile has become now regarded as a complete machine, not an assembly of parts picked up here and there.

On the other hand, when we consider the instruments required in production or the furnishing of a service, we find a decided tendency in the other direction, i.e., a tendency to purchase rather than to make them. Production of all kinds has continually become more highly specialized, requiring more highly specialized equipment and operations, and those who produce can no longer scatter their efforts in the direction of designing and building the variety of products that are necessary to carry on production. The machine tools required in a plant producing a metal product serve as a good example. No manufacturer, today, would attempt to make the machinery he uses to cut, grind, and polish, for the various operations have become so complex that he depends upon a number of suppliers to furnish the type of specialized machine required. No factory, today, would seriously consider, either, building its own cranes, hoists, conveyors, ventilators,

boilers, or air compressors, but would negotiate for the purchase of these from expert suppliers.

Thus, we have built up a situation by which all industries become more and more dependent upon one another as a source of supply for technical products, and what we call the industrial market has become of outstanding importance. The more highly specialized an industry becomes, the more it is dependent upon other industries. As we have seen, this is one reason why the purchasing function, as well as the distributing function, has grown in complexity and importance.

The industrial market can be visualized only by considering it from the viewpoint of a supplier of a particular product. We must distinguish between the "supplying" industry and the "consuming" industry.

First, let us consider what goods are used by industry. The following classification is illustrative of the various product groups, with examples for each group:

TABLE I

CLASSIFICATION OF GOODS USED BY INDUSTRY[6]

1. Machinery for production.
   - Machine tools.
   - Woodworking machinery.
   - Printing presses.
   - Pumps in a paper mill for handling stock.
   - Shoe-making machinery.
2. Auxiliary equipment.
   - Elevators in a manufacturing plant.
   - Heating and ventilating equipment.
   - Power-producing machinery.
   - Installed lighting equipment.
3. Operating supplies.
   - Fuel, water, buffing compounds, waste, small tools, printed forms, paper towels, etc.
4. Fabricating parts.
   - Gasoline engines for mounting on a machine, such as a concrete mixer.
   - Belting.
   - Gears.
   - The whistle on a locomotive.
   - Motors and controllers forming a part of a powered machine tool.

[6] From M. T. Copeland's classification of goods purchased by industry, appearing in Table I, pp. 27-8, of "Marketing Industrial Equipment," Bernard Lester, McGraw-Hill Book Company, Inc., New York, 1935.

5. Fabricating materials.
   Paint used on a Pullman car.
   Steel shapes for a machine bedplate.
   Insulating materials for a transformer.
   Cork gaskets.
6. Process materials.
   Dyes for textile products.
   Baking powder in the manufacture of biscuits.
   Coal for heating furnaces.
   Ice for cooling chemicals.
   Air for drying insulating products.
7. Primary materials.
   Iron ore, cotton, wool, wood, and copper.

With the above in mind as products to be sold, now let us consider the industrial market to be met, which follows in Table II.

TABLE II

The industrial market may be divided into the following principal purchasing groups:

Manufacturing companies.
- Process industries:
  - Chemicals.
  - Clay and brick products.
  - Coke.
  - Drugs and cosmetics.
  - Explosives.
  - Fertilizers.
  - Glass.
  - Leather.
  - Cement and lime.
  - Gas.
  - Paints, oils, and varnishes.
  - Paper and wood pulp.
  - Petroleum refining.
  - Rubber goods.
  - Soap.
  - Bakeries.
  - Canning and preserving.
  - Confectionery.
  - Dairy products.
  - Milling industries.
  - Ice manufacture.
  - Metal smelting and refining.
  - Steel works.
  - Foundries.
  - Tobacco.

Manufacturing companies—Con't.
- Metal-working industries:
  - Mechanical machinery.
  - Electrical machinery and supplies.
  - Automotive.
  - Locomotive and car builders.
  - Airplane builders.
  - Ship and boat builders.
  - Railway shops.
  - Farm machinery.
  - Miscellaneous metal-working plants.
- Textile industries:
  - Cotton.
  - Knit goods.
  - Silk and rayon goods.
  - Woolen and worsted goods.
  - Clothing.
- Lumber industries:
  - Planing mills.
  - Furniture and box.
- Miscellaneous.

Extractive industries.
- Mines and quarries:
  - Ferrous metal mining.
  - Non-ferrous metal mining.
  - Coal mining.
  - Quarries.

Extractive industries—Con't.
- Petroleum products.
- Natural gas.

Lumber industry:
- Logging and sawmills.

Construction industries.

Engineers and contractors.

Construction companies:
- General contractors.
- Electrical contractors.
- Heating and ventilating contractors.
- Plumbing contractors.

Public-service industries.

Electric light and power companies.

Steam railroads:
- Right-of-way.
- Rolling stock.
- Repair shops (*see* Metal working).

Electric railways.

Marine.

Airway.

Bus transportation.

Gas companies (*see* Process industries).

Public works:
- Highways.
- Water works.

Public Service industries—Con't.
- Sewage.
- Irrigation.
- Harbors.
- Canals.
- Bridges.
- Tunnels.

Communication companies.

Buildings.

Miscellaneous service industries.

Laundries and cleaners.

Amusements.

Printers and publishers.

Governments.

Federal:
- Department of Agriculture.
- Department of the Interior.
- Navy Department.
- War Department.
- Department of the Treasury.

Other:
- State.
- County.
- City.
- Township.

By selecting one of the products from Table I and searching for the possible purchasers in Table II, we find what the market is for the product. For instance, the manufacturer of printing presses would not attempt to sell his products to "airplane builders," but would look to "printers and publishers" and some few large organizations in other industries that might happen to do their own printing work. On the other hand, the manufacturer of such common classes of equipment as pumps, compressors, fans, and blowers would find a market from a large number of industries and possibly all. Thus, we see the market from industries is *selective*,[7] depending upon the product offered for sale and the industries which may constitute the market.

Probably the steam railroads of the country offer a market for the greatest variety of technical products, because, when the various kinds of activity included in construction, maintenance, and operation are considered, we then find that they employ products which are used so

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[7] See "Classification of Machinery and Equipment," p. 50, "Marketing Industrial Equipment," Bernard Lester, McGraw-Hill Book Co., Inc., New York,

CLASSIFIED PURCHASES, CLASS I RAILROADS, 1937

Frogs	$44,722,000
Track tools and miscellaneous	5,904,000
Interlocking and signal and Tel. & Tel.	17,526,000
Brick, cement, lime, stone, etc.	7,430,000
B. & B. lumber and piling	14,743,000
Switch ties	11,567,000
Crossties	58,477,000
Bridges, turntables, etc.	1,866,000
Ballast and riprap	16,387,000
Rail—new and usable	43,098,000
Fuel and water, station material, etc.	6,795,000
Chemicals for timber treatment	2,787,000
Total Maintenance of Way & Structures	$231,302,000
Bolts, nuts, washers, etc.	$15,978,000
Springs	2,649,000
Boiler tubes, superheater units, etc.	6,500,000
Tubing and soft metals	4,227,000
Bar and sheet iron and steel	36,428,000
Locomotive and car forgings	24,014,000
Locomotive and car castings	52,518,000
Brass castings and journal bearings	35,549,000
Air brake material	9,082,000
Locomotive appliances	15,146,000
Passenger car trimmings	10,435,000
Electrical materials	17,486,000
Shop fuel	8,691,000
Foundry supplies, firebrick, clay	1,078,000
Wheels, tires, and axles	33,392,000
Locomotive and car lumber	23,552,000
Machinery, boilers, fireboxes, and miscellaneous	13,109,000
Total Maintenance of Equipment	$309,834,000
Train and station supplies	$14,726,000
Oil house material	22,460,000
Ice house supplies	9,166,000
Fuel for locomotives	279,534,000
Commissary supplies	17,125,000
Total Conducting Transportation	$343,011,000
Iron and steel pipe and fittings	$7,726,000
Electrical material for buildings	5,149,000
Hardware	15,812,000
Rubber and leather	8,974,000
Glass, drugs, paints, etc.	25,641,000
Stationery and printing	17,449,000
Miscellaneous and unclassified	17,698,000
Total Common to All Departments	$98,449,000
GRAND TOTAL	$982,596,000*

* Includes $11,249,000 of unclassified materials for equipment built in Pennsylvania Railroad shops.

Purchases other than ties, rail, and fuel estimated on the basis of reports from 29 railroads, subject to revision.

largely by industries generally. The tabulation [8] on page 327 shows a classification of the products purchased by the Class I steam railroads of this country in 1937, a large share of which may be seen to be technical in character.

Reference has already been made to the migration that is continually taking place in industry for economic reasons, such as altered local conditions due to taxation, labor supply, availability of raw materials, and shifting in the market for the products made. The student can visualize these changes over a period of several years for all manufacturing industries according to sections of the country from the following table,[9] thus illustrating the shifting locations of industrial markets.

PERCENTAGE OF TOTAL OF MANUFACTURED GOODS

Region	1909	1919	1929	1935
New England	12.9%	11.5%	9.1%	8.8%
Middle Atlantic	34.5	31.8	30.4	28.0
East North Central	25.2	28.4	30.9	31.7
West North Central	8.7	8.3	7.6	7.2
South Atlantic	6.7	7.1	7.5	9.1
East South Central	3.0	2.6	2.9	3.3
West South Central	3.0	3.7	4.0	4.2
Mountain	1.8	1.4	1.8	1.4
Pacific	4.1	5.1	5.9	6.3

[8] Tabulation reproduced from *Railway Age*, January 1, 1938, p. 55.

[9] Tabulation from "Industrial Markets," *Business Week*, June 12, 1937, p. 18.

CHAPTER XIV

THE DISTRIBUTION OF TECHNICAL PRODUCTS

THE IMPORTANCE OF DISTRIBUTION

Reference has already been made to our national progress in the design and manufacture of technical products. Concentration upon such problems has engaged many of our brightest minds, with the result that today we are equipped or can equip ourselves to produce almost any product efficiently and economically. Production is supported only by a market, and a market should be served only by a system of distribution which adequately reaches it in an economical manner.

More emphasis is therefore being continually given to efficient distribution, in order that the established wheels of production may move at an even and steadily accelerating pace. In a solution of the problems of efficient distribution, greater recognition is being continually given to the necessity of applying engineering principles, for distribution is approaching the state where it may be termed an exact science. All about us we find men trained as engineers, devoting their attention to distribution problems and contributing liberally to the development and administration of improved distribution systems and processes. Moreover, those engaged in solving problems of design and production should understand not only market requirements affecting the products, but especially those characteristics relating to the product which make distribution easier and less costly. With such an understanding, engineers can assist in a solution of the problems of distribution, through their design and production activities.

Distribution, as we shall see, is definitely an economic function, since it relates to the process which goes on in getting the completed product from the factory, where it is produced, into the hands of the customer where it may be found completely performing those functions for which it is intended. Whether the product is so made that it may be easily packed, stored, shipped, installed, and serviced is, for instance, vital to its efficient distribution and acceptable use.

A DISTRIBUTING SYSTEM IS AN ECONOMIC ENTITY

A manufacturing establishment immediately appeals to the eye as something of great value. In it we see machinery, and a production layout which actually produces physical objects of utility not existing before. They can be measured, weighed, and priced, and we are impressed with the importance of production, because at a given place we can see physical objects of value rapidly and continuously come into being, under the direction of an organized group of individuals. We all enjoy seeing things made and the direct results of machines and men working together.

Distribution, however, we can never see in all its phases. Here and there we recognize products in course of transportation, on display, or being installed, but, to the average individual, distribution is not easily visualized, and a complete distributing system is nebulous and indefinite. Since it cannot be seen and felt and carried on at one place as manufacture can, a definite value is not easily attached to it. Though any distributing system requires physical properties such as offices and warehouses and mechanized systems for communication, product handling, and the maintenance of records, these are a small part of its value. It consists primarily of organized personnel, carefully selected, trained, and directed, comprising a vitalized operating unit. The economic investment in such an organization is just as real as for the manufacturing plant. The products of distribution consist of customers' orders which the manufacturer is to fill, and from which physical production is set in motion. Vast sums are often required to build up extensive distributing organizations, which parallel investments made in factories and production facilities, but much of this value consists of trained personnel.

DISTRIBUTION INVOLVES MANY HUMAN FACTORS

If any one of us were charged with the responsibility of directing the distribution of a manufacturing establishment which was starting to make and sell a particular line of product, we would find ourselves faced with a large variety of problems relating to organization and procedure. The decisions leading to an answer to these problems would, in a large measure, depend upon a group of conditions many of which were neither definite nor exact, and judgment would find ample opportunity to display its skill.

Let us imagine that the product consisted of a line of fans and blowers ordinarily used in connection with ventilating systems found

in most public buildings and industrial plants. In conference with those responsible for design and production, some decision must be reached as to what sizes and types should be offered for sale, and what variety and number should be placed in regular production to take care of the anticipated demand. Market studies should already have been made to provide some guiding facts, but with the need for setting up a production schedule, definite figures must be furnished the manufacturing department, not only for the immediate future, but with a lesser degree of accuracy for a period of several months ahead. Such facts as general business conditions, probable volume of public and private commercial construction and industrial building work, the extent and productivity of the distributing organization, the extent of necessary stocks of fans and blowers to be accumulated, the results to be expected from sales promotional and advertising activities, as well as others, would have to be carefully considered and the resultant figures evaluated.

Each of the factors would have a relation to all the others, and each decision would have to be based upon an attempt toward reaching the most economical procedure. Obviously, if greater quantities of a single item, or a group of items, were built, they could be more cheaply made than in smaller quantities; yet the risk of overproduction of a single item, and the consequent accumulation of inactive warehouse stocks, are responsibilities those in charge of distribution must share. They are the eyes and ears of the manufacturing company and through them the market demands are translated to production officials.

Shall distribution be attempted over the entire country or only over a selected territory which can in time be extended? Shall prospective customers be reached by employees of the manufacturing company, or will it be better to select distributors or agents to do this work, leaving only their supervision and guidance to company sales employees? Must we look to heating and ventilating contractors as a form of outlet? Will architects and engineers influence the business to be obtained? How long will be required to train employee salesmen or distributors, as the case may be? Such questions as these, together with many others, must be answered in order to form a sound plan of distribution.

One of the most important matters which must receive our attention relates to the commercial conditions under which these fans and blowers are to be distributed. How will the various items be priced, and what terms of payment will apply? In what form will descriptive

literature upon the product, as well as pricing instructions, ordering instructions, delivery data, be prepared so as to be most useful? Competitors have been reaching this market, and if prices are made too low, unfavorable reaction will result; but if too high, sales will be retarded and sales personnel may become discouraged. It would be quite easy to establish a precedent in this regard which might serve as a serious setback in launching a product successfully to the market.

Thought must also be given to the continued successful operation of the product after it reaches the ultimate users' hands. Troubles must be corrected quickly, no matter what the cause might be. Some plan of servicing the product will hence be necessary.

We can take still another example. Suppose that a small magneto-type telephone system is taken over by an organized telephone system and that a complete renovation is contemplated in order to bring this newly acquired system up to date. For rendering such technical service it is just as important to have the right method of distribution as for a technical product that is manufactured and sold for use.

First of all a study of existing traffic is necessary. How many existing subscribers are there, and to what extent do they use local and toll service? With improved service facilities, to what extent will existing traffic increase, and how many new subscribers can be added? What increase in rates would be justified to support the investment for modern equipment and for furnishing improved service?

Technical questions must also be answered regarding the equipment layout. Should the magneto-operated system be changed to the common battery system, or would it pay to go so far as installing automatic switching? Should there be a relocation of lines, and should these be placed on poles or underground? Would the French type of receiver be justified on the basis of its greater acceptance? From a study of the present and probable future "center of gravity" of the system would it be desirable to relocate the central operating office? What should the immediate capacity of the switchboard be, and what provision should be made for the future? Where will "pay phones" justify their location?

How many employees will be required, and should the old hands be retained? How will employees be selected, trained, and paid to obtain the best results for themselves and the company?

Only a few of the questions that arise in determining a method of distribution for this form of service have been mentioned here. These, it will be noted, combine problems of an economic and technical nature, and also human factors. Some can be answered with mathematical

accuracy; others depend on judgment. From a detailed study and evaluation of facts and assumptions must come the answer as to what economic form of distribution should be adopted.

Distribution is therefore not an exact science. It includes factors of human likes and dislikes, and is quite different from the machining of a casting, where exact drawings, machining templates, and tools in the hands of the operator serve in turning out a product with definiteness and accuracy.

WHAT DOES DISTRIBUTION INVOLVE?

The purpose of distribution is a simple one. It consists of making it possible for the ultimate purchaser to obtain and retain a product or service in usable condition as easily and as cheaply as possible. How is this accomplished?

Let us consider for the moment a manufacturer of cast-iron gears and pinions. To guide and regulate production, the types, sizes, and quality range of the product, together with the quantity to be made, must be considered and determined. After manufacture, these gears and pinions must be stored at some point or points, for no widely used product is purchased and put to use immediately upon its completion. To dispose of these gears and pinions, some contractural relationships are necessary in written or concrete form with those who provide facilities of distribution, and some forces must be at work exploiting the product and negotiating with prospective purchasers and completing the transactions. The gears and pinions must be properly packaged after they are made, and then transported, for they pass through one or more hands before reaching the ultimate user. After purchase has been made, payment must follow, and funds must be collected and turned back to support all phases of activity. All the operations we enumerate here must, of necessity, be measured and recorded, and likewise they must be financed; all, too, involve risks to be borne, caused by imperfect human judgment, error, and accident.

We know that we cannot consider the general function of distribution as complete until the product has been delivered to the ultimate purchaser in a satisfactory operating condition and has been paid for by him. Thus, we find distribution made up of a number of functions, all of which contribute to this end, but only one of which constitutes the actual selling function. Several functions of distribution are allied with other functions which engage the attention of the manufacturer.

These functions of distribution may be summarized in the following way:

Allied with manufacturing activities:
- Establishing demand requirements on which to base production rates and quotas.
- Correct and prompt filling of orders or other product commitments.
- Packing the product for storage and shipment.
- Factory warehousing.

Allied with transportation activities:
- Shipping the product.
- Transporting the product to customers, resellers, or local stocks.

Allied with selling activities:
- Determining the market characteristics.
- Determining the channels of distribution for the product.
- Contacting distributors, customers, and prospective purchasers.
- Establishing conditions of sale—contract relationships, price, delivery, terms, and the like.
- Negotiating orders.
- Sales promotion and advertising.
- Local warehousing.

Allied with service and installation activities:
- Rendering maintenance service upon the product furnished.
- Rendering installation service, where the nature of the product requires it.

Allied with financial activities:
- Credit investigation of purchasers.
- Establishing terms of payment upon orders placed.
- Collecting payments.

It is well for the student to fix in his mind these various functions and the relations between them, for all are necessary to successful and economical distribution. Owing to the importance of such matters as market determination, sales promotion, price and pricing policies, warehousing and maintenance service, these subjects are treated elsewhere, at length, and we will devote our attention here, largely, to those phases which are related directly to selling activities.

The performing of each of these functions represents a division of labor which goes to make up an entire distributing system. In the larger industrial organizations, the work of individuals is highly specialized, but in the small organizations one or a small group of individuals may perform several functions. Then, again, some of these functions may be regularly purchased as a form of service from an independent business organization that specializes in such service. For instance, a small industrial company may engage others to warehouse its finished stocks, attend to its advertising, or render maintenance or installation service upon products manufactured. Where products are

sold upon a partial payment plan, it is customary for the manufacturer to depend upon a financing company to furnish this service.[1] Very large companies sometimes establish their own financing companies, but they are always operated entirely separately, for financing is a highly specialized undertaking.

THE DEVELOPMENT OF DISTRIBUTING CHANNELS

We have seen how human effort has been specialized in activities relating to the design and manufacture of technical products. Correspondingly, specialization and standardization have taken place in connection with distributing activities. Originally, the individual who became skilled in making a product for his own use found that his neighbors were willing to purchase such products from him. With an increased demand, he became able to produce a better product more cheaply, and became more broadly known as a supplier. As the circle of customers widened, the functions of distribution became more pronounced, and the problem of serving them more complex. This led to employing others than the individual producer to distribute the product, and individuals and finally separate organizations came into existence specializing entirely upon selling a particular product, or group of products, to an existing market. Products increased in variety and complexity, and customers' demands became more exacting and technical, so that such problems as creating and administering the distributing organization became of prime importance.

Manufacturers, as they developed systems of distribution to reach an ever-widening market, found increasing difficulty in operating, as well as financing, constantly expanding distributing organizations. Retailers entered the picture as independent local organizations, which devoted their entire time to distribution over a small area, and these retailers also took on a variety of products, made by different manufacturers. As these areas further grew in size and purchasing density, the retailer found that he, too, was unable to keep in close touch with the local market, and some of them gradually assumed a position of wholesalers and developed local retailers, compensating their effort by giving them a share of the gross profit for the services they performed.

[1] Financing companies furnish a manufacturer of a product sold on time with a complete financing service, by which the manufacturer receives prompt payment in full for the product sold. The financing company provides a simple system of doing this, and after the sale is made attends to all matters of collection. Its compensation consists of a service fee including interest charges, which comes from an addition made to the retail price of the product. Usually, some form of guarantee or endorsement is required of those who make or sell the product.

Thus, the manufacturer, who originally sold his products locally direct to the ultimate purchaser, found a new set of problems to be met in distributing through various wholesale and retail channels. In short, the manufacturer became continually further removed from the ultimate buyer, so far as his operations were concerned, and a greater share of the price the ultimate purchaser paid went toward distribution expense.

Within more recent years, the manufacturer has made an effort to gain a closer contact with those who do and can use his products. We all realize the satisfaction that comes through doing business "with the manager" and receiving his personal attention to supplying our wants. Nevertheless, we realize that it is impossible for the manager or head of a company to care personally for each customer's needs. As manufacturing organizations have grown, they have, with many classes of products, been confronted by the dual problem of developing and maintaining active and efficient secondary outlets of distribution, and, at the same time, preserving a close contact with the ultimate purchaser whose needs are constantly changing in character. Certain technical products, as we shall see, continue to be sold direct to the ultimate purchaser, but, on the whole, a growing share passes through the hands of distributors of some sort.

THE KINDS OF DISTRIBUTING CHANNELS

Every producer is faced with establishing a policy of distribution, and usually a selection must be made from a variety of available methods.

Any plan of distribution to be effective and economical must be based upon a thorough knowledge of the product to be *distributed*, the *market* to be served, the *possible channels* of distribution, and the *activities of competitors* who supply similar or competing products.

Ordinarily, the channels which are open to the supplier are these:

1. Direct from the producer to the user, the producer performing the main distribution functions with its own organization and personnel, and transferring the title to the product direct to the ultimate user.

2. Through agents who act for the producer or principal in performing the functions of distribution. As such, they do not take title to the product and make a profit upon reselling it, but rather they receive compensation for the functions or services they perform.

3. Through independent companies whose business it is to purchase and sell again. In this group fall the following:

Wholesalers or *jobbers* who buy and sell exclusively to the small local dealer, who in turn sells to the ultimate purchaser, or in addition thereto sell direct to ultimate purchasers whose requirements are large.

Contractors who purchase products to incorporate in a structure or construction project, such as a building, ship, bridge, ventilating system, or power house.

Manufacturers who purchase for the purpose of completing the product they make and sell; for instance, a pump builder will buy an engine or motor to complete a saleable unit, or an automobile builder will purchase tires.

Dealers or *retailers* who purchase from the producer or from the wholesaler or jobber, and in turn sell to the ultimate user.

Since technical products are highly specialized in nature, specialized distributors have appeared in each class of channel named. Some handle only one make of a particular product; others handle two or more makes, in order to give the ultimate purchaser a choice on such matters as quality or price.

HOW DISTRIBUTING OUTLETS OPERATE

Electrical-Appliance Dealer. In a small midwestern town is a successful retailer of household electrical appliances. The establishment is owned and operated by two men who have formed a corporation for the purpose of making a profit through the purchase and resale of standardized products of recognized quality.

This company has business headquarters on one of the leading side streets of the town. Since much of the selling is done in the purchaser's home, rather than from the store, and since the product sold is in the nature of a speciality, a prominent location on the main street of the town is not justified. At the store, however, stocks of appliances and supplies are carried and displayed, shipments are made, books and business records are kept, and in the rear of the place minor repair work is done.

One of the owners devotes his time to interviewing customers and prospective purchasers, demonstrating the larger household electrical appliances in the homes of the prospects, and making sales. In this work he has the assistance of a younger man who operates also as a salesman.

The other owner makes his headquarters entirely at the store, attending to important customers or prospective purchasers as they come in and demonstrating to them articles offered for sale. Assisting him are a bookkeeper, stock and shipping clerk, and a repair or service man.

Delivery service is obtained from a local trucking concern, which brings in much of the purchased stock from the local railroad station and delivers the individual sales to the homes of the purchasers.

These policies govern the operations of this local retailing company:

> Every effort is made by the owners to become an active part of the community in which they live, through studying the tastes and desires of the purchasers.
>
> Responsibilities are definitely assigned to each individual in the employ of the company.
>
> For a given class of product sold, only one make is handled, and upon this the company has exclusive distribution privileges within the community.
>
> Selling prices, established by the manufacturer, are invariably maintained, the only exceptions being for shop-worn items and obsolete models.
>
> Larger items, such as washing machines, refrigerators, and electric ironers, which require no permanent installation, are furnished to reliable prospective customers on 30-days' trial, and demonstrations are given in prospective purchasers' homes wherever possible. All products carry a guarantee of one year, supported by the manufacturer.
>
> All items selling for approximately \$20 or more may be purchased on time, the cost of financing being a part of the sales price. Financing is done through one of the leading household financing concerns. Deliveries are made without charge to all purchasers in the community.
>
> A most careful check is made of the amount and variety of stock items carried, with a view to ordering only the class of products for which there is a demand, and these in quantities which will be disposed of within a period of three months.
>
> Purchases are made from wholesalers and distributors which represent the manufacturers over wide areas, including the town in which this retailer is located. These companies supply complete selling plans upon the products they furnish, together with necessary literature and sales promotion material, which originate with the manufacturer. Most of this material is furnished the retailer at cost, and he makes use of this; he shares with the wholesaler or manufacturer the cost of advertising in local papers.
>
> In selling a given manufacturer's product line, it is understood between this retailer and the supplier that, should the supplier receive any inquiries from prospects located in the dealer's territory, these inquiries will be promptly turned over to the dealer for the solicitation of business.

Machine-Tool Dealer. In one of the large cities in the East, there is a machine-tool dealer who specializes in the sale of metal- and woodworking tools for purposes of production. The company is incorporated and owned by several individuals, most of whom are officers and

employees. Over a period of years, they have been supplying machine tools to a large number of industrial plants located in the territory they serve, which extends over three or four states.

Machine-tool builders are peculiar, in that most manufacturers specialize in building one or a small variety of tools, such as lathes, planers, boring mills, and the like. On the other hand, almost all industrial plants buy a variety of machine tools, either for purposes of production or maintenance, or both. Thus, it is often more economical for distribution of machine tools to take place through retailers who can handle complementary lines of tools, and thus furnish a complete line to the ultimate user.

The machine tool dealer that we refer to here has established exclusive distributing connections with some eighteen tool builders, and acts as their representative over the territory covered. No two manufacturers which this company represents build the same kind of tools; yet this company can supply its customers with any of the common classes of tools required.

This machine-tool dealer has offices in a convenient location, and a small warehouse on the outskirts of town. Employees consist of some fifteen salesmen, warehouse clerks, bookkeepers, and a stenographic force. The salesmen are assigned to divisions of the dealer's territory, and each one sells the complete line of tools handled by the dealer. These men, without exception, have had practical experience in the operation of factory machinery, and they understand production processes thoroughly. In reality, much of their work is analyzing the production operations of their customers in an endeavor to find better and cheaper methods of operation by means of tools which they can furnish. Most machinery sold is built on order by the manufacturers this company represents, for only a small stock is carried, and this consists largely of standardized small units such as power saws, small drill presses, or pedestal grinders. Although the majority of sales made include machines which are standardized but not built by the manufacturer for stock owing to the limited sale of duplicate units, in several instances a study of the customer's requirements resulted in the necessity of highly specialized machines including design modifications for the particular job. In such cases, the salesman for the machine-tool dealer calls for the assistance of a factory representative whose experience in design helps him in determining exactly what is required.

Distribution, therefore, in this instance, is through highly trained sales engineers, supplemented, as occasion arises, by skilled factory representatives, and consists of furnishing both an engineering service and a technical product. Prices are set by the manufacturer and listed

in his catalogue on standardized machines, and specialized machines are quoted individually to the machine-tool dealer, who, in turn, quotes to the customer. The dealer's gross profit consists of a discount upon the prices quoted. He assumes title to the product and resells it to the final purchaser, assuming all credit risks and the cost of obtaining and filling orders.

Manufacturer's Agent. In the coal fields of West Virginia, there is a man who is in close contact with the coal operators and mine superintendents. He has a small office which he shares with an insurance agent, secretarial service being provided. In this territory, he acts as a selling agent for a manufacturer of a small variety of machines used principally in mines. His entire work consists of studying the problems of the mines, determining wherein the machinery he handles can be used, and making the sale. Having formerly operated mining machinery, he knows the language of the miner, his likes and dislikes, and is able to detect when additional equipment is being considered.

His operations are based upon an agreement which has been in force for some years with the manufacturer whom he represents. This agreement calls for the exclusive use of his services on a basis of a percentage upon sales made. Such office and traveling expenses as are occasioned are borne by this representative or manufacturer's agent. The manufacturer assumes all credit risks, renders invoices direct to the ultimate purchaser, and makes collections. Occasionally engineering assistance is rendered the manufacturer's agent, for instance, where highly specialized equipment not ordinarily built is being considered. All major cases of maintenance service are handled by the manufacturer, although repair and renewal parts of the machinery are sold by the agent.

Reference

Walter Amory Allen, "Effective Distribution Through Manufacturers' Agents," *Industrial Marketing*, November, 1935, p. 9.

The Wholesaler or Jobber.[2] The wholesaler or jobber is one who purchases from the manufacturer, presumably in large quantities, and sells to the retailer or to those ultimate purchasers who are large buyers.

[2] Today, the terms "wholesaler" and "jobber" have come to be used synonymously. The meaning of the word wholesaler, however, has altered, for he sells no longer exclusively to the retailer. The wholesaler in the field of mechanical and electrical supplies usually sells not only to retailers but also to contractors and large users such as public utilities and railroads. The term jobber is still less explanatory, for originally it applied to the business concern which made a practice of buying in large "job lots" and selling in smaller quantities.

In most classes of business, such as hardware, plumbing, or electrical supplies, a large variety of products is required, and these are furnished by a large variety of manufacturers, many of whom specialize upon a relatively small number of products. There is a place, therefore, for an organization which falls between the manufacturer and the local retailer, in an economic scheme of distribution. The condition most conducive to the successful operation of the jobber is that where wide territories are involved, because, since he collects and offers for sale a wide variety of related products, he can afford to reach more distant points where the demand for any one product may be very small, but collectively a material amount. He thrives under those conditions which provide a large number of potential users of well-standardized products, who require prompt delivery service. For products of a technical nature, any high degree of sales engineering skill cannot be expected, owing to the large variety of products sold by one individual jobber salesman. His operations are suited, rather, to products which commonly fall into the class of merchandise.

We may summarize the functions of the jobber which interest us most as these:

1. Assembling and offering for sale lines of apparatus, equipment, and supplies, which are related to one another in meeting a market.
2. Maintaining active contact with retailers and large ultimate purchasers.
3. Extending credit, rendering invoices, and making collections for goods sold.
4. Carrying large stocks which make quick delivery possible.

Wholesalers and jobbers purchase direct from manufacturers, many acting as exclusive distributors; they do business on a relatively small margin of profit and rapid turnover. They often issue their own catalogues, which cover a vast number of items, information upon which is furnished by the various manufacturers.

Other Manufacturers. A manufacturer naturally endeavors to put out a product which will, as fully as possible, meet all the requirements of the purchaser without the necessity of anything being added to it. Automobile builders have long since learned to supply the car with all accessories which most users customarily need. Furthermore, a large share of manufacturers, giving careful consideration to the benefits of specialization in effort, refrain from attempting to manufacture too wide a variety of component parts for the completed piece of equipment they build, but prefer, instead, to purchase some parts from other manufacturers. Such conditions as these have brought about a large

market, between builders of technical products, for completed parts of great variety to be used as component parts of other products.

The gas-engine builder may require a magneto or a battery to make his engine complete, and, rather than specialize in the manufacture of magnetos and batteries, he purchases them from another concern. He may also find that there is a demand for gas-electric units, and, having no inclination to build electric generators and control equipment, he therefore is glad to purchase them. The builder of pumps finds a market for the pump mounted as a complete unit with the source of power, either an electric motor or an engine, and arranges for an external supply of these power units.

Distribution in cases such as these is a comparatively simple matter. Engineering skill may be required properly to select and adapt one class of equipment to the other in order to supply a well-balanced whole. Purchases are usually made in quantities of duplicate units. The demand may be a continuous one, for in reality the supplier might be considered as an aisle or section in the purchaser's plant, for he furnishes a component part of that which is ultimately produced just as any part which the manufacturer himself builds. In view of these conditions, it is customary for the supplier to sell to the other manufacturer direct where the latter is a continuous purchaser, and not through resale channels.

The purchaser, in such instances, can also be regarded, from the viewpoint of the supplier, as a specialized distributor, for he reaches a market which the supplier himself cannot reach, owing to the interest of the purchaser in obtaining a complete article. For instance, the purchaser of gasoline-driven air compressors, so commonly seen in use for road construction and repair, desires a complete ready-to-run unit, consisting of compressor, engine, and pressure control, all mounted upon a chassis on wheels. The compressor builder who assembles and sells the complete unit may make neither the engine nor the air tank, and does no work whatever in their fabrication. His function is to engineer the entire unit, and to distribute it.

Contractors. Contractors purchase technical products to use themselves, for instance, in creating an engineering structure, or to form a part of the structure itself to be used after it is completed.

The contractor erecting a residence may require a power shovel, rock drill, or floor-surfacing machine, which he purchases and uses in his business and in the construction of the building. On the other hand, he may purchase an electric refrigerator or air-conditioning unit which will become a part of the home to be used by the occupants. The

contractor may, therefore, be both an ultimate purchaser and a channel of distribution for the supplier of equipment.

In the construction field, there are two classes of contractors who use technical products extensively: the *general contractor*, who may take over the entire contract for the construction work, whether it be a residence, public building, bridge, dam, or sewer; the *subcontractor*, who does a particular part of the work requiring specialized knowledge and experience, such as the heating and ventilating, plumbing, or electrical wiring. The general contractor usually buys little in the way of equipment other than that which he purchases from time to time for construction purposes. The subcontractor, on the other hand, being responsible for furnishing a specific part of the installation requiring equipment as well as labor and which must be carefully engineered, is a frequent purchaser of equipment actually becoming part of the installation, and as such he is an important link as a retailer in the system of distribution.

The *consulting engineer* or *architect*, by means of a set of specifications which he prepares, determines the type and quality of the apparatus and equipment which the contractors furnish, although the make of such products is usually determined by the contractor himself. Often the functions of the engineer and the contractor are combined in one company, and several large companies exist which undertake the complete engineering and installation work upon construction projects such as power houses, public buildings, and mills.

Contractors purchase both direct from the manufacturers of equipment and from wholesalers or jobbers—usually apparatus from the former and supply items from the latter. Since they purchase only to fulfill the requirements of a particular installation, and in no sense consistently represent the supplier, they perform rather a perfunctory function in the system of distribution from the supplier's viewpoint. For those who are to own the completed installation, they perform a purchasing function.

SELECTING DISTRIBUTING CHANNELS

The distributing policy to be adopted by any manufacturer constitutes a decision of the greatest importance, and may be a determining cause for success or failure. The principal factors leading to a decision relate to:

(*a*) The type of product manufactured, and the extent of the product line.

(*b*) The resources and facilities pertaining to the manufacturer, which

may or may not permit undertaking distribution direct to the ultimate customer.

(*c*) The type of market for the product, and the market requirements.

(*d*) The existence of available reselling outlets which might be utilized for distribution.

These factors must be considered together, not only with a view to existing conditions, but also with regard to future probabilities.

The three illustrations that follow—that of a manufacturer of large machinery, a large manufacturer of electrical apparatus, and a manufacturer of a line of electrical wiring supplies—will serve to illustrate the logical manner in which distribution channels are selected. By carefully weighing factors that relate to the four principles outlined above, it is usually not an exceedingly difficult problem to select an economical and reasonable distributing channel.

"Case Studies in Industrial Marketing," appearing in various issues of *Industrial Marketing*, give a good insight into typical industrial distribution organizations. At the present writing, 19 cases have appeared, in the following issues: April, May, June, July, August, September, October, November, and December, 1936; March, April, May, June, August, and December, 1937; March, April, and July, 1938; February, 1939.

J. M. McKibbin, Jr., "A Plan for Securing Sound Distribution," *Industrial Marketing*, January, 1936, p. 9.

Carl Reynell, "Buying Through the Distributor," *Mill and Factory*, May, 1938, p. 61-2.

Wm. S. Acuff, Jr., "The Economic Phase of Marketing Through Distributors," *Industrial Marketing*, May, 1938, p. 38.

A Manufacturer of Large Machinery. Consider, for instance, a manufacturer of steam locomotives. Such apparatus, in itself, is large and costly, and built to fill specific orders of purchasers. Considerable technical knowledge is required to determine the kind of locomotive suited to the particular operating conditions. Sales usually are made singly or in small quantities, and decisions to purchase are reached only after due consideration by higher executives in the purchasing organization. The number of customers is relatively few, for customers consist of railroads and large industrial establishments that have haulage problems within their own plants. Hence, the market is limited, and purchasers usually easily identified. The number of sales engineers required is few, and they must be mature men of technical experience and business standing who can interview railroad and industrial execu-

tives, although a certain volume of business coming from repair parts and other details may be handled largely as a matter of routine.

Under such conditions as these, there is little need for employing resale outlets, and the manufacturer can reach the market in the most economical way by distributing the product direct to the ultimate purchaser.

If, on the other hand, this steam-locomotive manufacturer extended his line of product to include other products purchased by railroads, power plants, industrial companies, and mines, and undertook to build and distribute such products as Diesel engines, pumps, and compressors, the market would have widened considerably. If such products were inclusive as to types and sizes, the number of possible customers would include all industries and a group of purchasers which would reach several thousands in number, including such purchasers as garages, dairies, machine shops, and public and private institutions.

The manufacturer would, at once, be confronted with the problem of establishing resale outlets, for distributing direct to all classes of purchasers in all localities would become a herculean task and require organized talents, administrative ability, and capital outlay beyond ordinary reach.

Even though the manufacturer might provide an extensive line of equipment for a wide variety of purchasers, still certain lines of product could be distributed only by the direct method, whereas for others, distributors would be employed.

A Large Manufacturer of Electrical Apparatus. Some manufacturers making many products necessarily use a varied scheme of distribution. The following synopsis will show the avenues through which this manufacturer sells his products, in addition to selling to the ultimate user direct.

Figure 1 is a diagram of the various ways in which this manufacturer may reach the ultimate user. For each product manufactured, the following determining factors must be considered in deciding which methods of distribution shown by **Fig. 1** will be applicable:

1. Size and selling cost of product.
2. Kind of product—engineering and application problems involved in selling it.
3. Kind of market—concentration, number and size of buyers, buying habits.
4. Necessity for introduction as radically new products.
5. Maintenance service of a technical nature required.

After a careful study of each product manufactured, the following methods of distribution, as shown in the middle column of the tabulation, were selected as best for each particular product line. The principal factors determining these selections are indicated by the numbers in the right-hand column, these numbers referring to the five determining factors just listed:

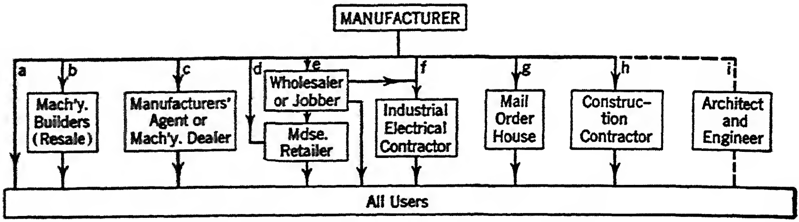

FIGURE 1. Channels of distribution through which the manufacturer may distribute his products.

Product	Selected Methods of Distribution	Principal Determining Factors in Selection
Turbo-generating units, Large transformers, Substation equipment	a–h–i	1–2–3–5
Electric and Diesel locomotives	a–h–i	1–2–3–4–5
Motors and control	a–b–c–e–f–h–i	1–2–3–5
Air-conditioning equipment	a–c–i	1–3
Electric furnaces—industrial	a–i	2–3–4
Gearing equipment	a–b–c	1–2
Electrical merchandise	d–e–g	1–2–3
Lighting equipment	a–e–f–h–i	1–3

A Manufacturer of Supplies. Considering now the distribution problem of a manufacturer of a complete line of electrical wiring devices, we find this line of product to consist of a very large number of standardized items for which the demand is consistent.

Purchases are made by electrical wiring contractors who make the selection and application of the various items according to the need of the installation. No high degree of engineering, therefore, is required in the distribution.

The market for this company's products is widespread, for they are used in applications by all consumers of electricity. Electrical contractors are found in almost every town and hamlet, numbering many thousands in this country. Most items are required in small quantities, and must be readily available for prompt delivery, for the contractors need them as they proceed with the installation work they are doing.

Wiring devices, however, are not the only items in a complete line of electrical supplies; many others, such as light bulbs, cable, conduit, and lighting fixtures, are included. In this country in the larger cities there are electrical wholesalers who handle all these items. Such companies as these can, therefore, economically distribute the wiring devices made by this manufacturer, and reach the market from the electrical contractor. Through wholesalers, then, with a complete line of products, supplemented by those supplied by other manufacturers, the manufacturer of wiring devices can economically reach the contractor, and finally the ultimate user.

WAREHOUSING AND MAINTENANCE SERVICE

Warehousing. As we follow production and distribution from the original source of raw materials to the finished product as furnished the ultimate user, we find reservoirs for the storage of goods throughout the entire route. Some are large and require extensive facilities; others are small and often insignificant. Some are used for the accumulation of raw materials, parts or semi-finished products; others are devoted to the storage of completed and packed goods ready for use. If production could be arranged so that all the elements required would reach the spot where they are used at the exact time they are required, and if consumption took place immediately upon the completion of production, there would be little need for these accumulations, except for those products whose price varies and the purchaser gambles upon such variation, buying more than is required when prices are low and hoping for a rise. But such conditions do not hold true for a variety of reasons.

Many of the steel manufacturers in this country obtain their ore from the North near Lake Superior. Navigation between Duluth, and such cities as Chicago, Detroit, and Cleveland is impossible during the winter months, although the blast furnaces may operate during the entire year. A great volume of iron ore must therefore be stored near the furnaces, reaching its maximum usually at the close of the summer navigation period, in order to provide for continued operation during the late fall, winter, and early spring. Iron ore can be satisfactorily stored out-of-doors in large piles accessible to the furnaces, to which it is carried by large hoists and conveyors.

A manufacturer of household water system equipments requires a large number of machine screws in the assembly of pumping apparatus. These are purchased from an outside supplier, and when bought in large quantities can be obtained very cheaply. It is found that the

greatest economy can be achieved by buying all at once a supply which in ordinary times of business activity will last six months. These must be stored in a clean dry place, and in containers convenient for handling and use. An accurate running record must be maintained of the quantity in stock at any given time.

This same company requires a large number of valves, which can be most economically manufactured in quantities at a higher rate of production than they are consumed. Provision is therefore made with special machinery to make these valves at periodic intervals in large quantities and store them in the stockroom, from which they are withdrawn to meet the demands of the assembly divisions of the factory. Stocks are therefore accumulated, not only so that the items are available as needed, but also as a result of economical production.

Electrical jobbers sell a complete line of apparatus and supplies required by the electrical contractor, including such items as wire and cable, connectors, insulators, conduit, switches, meters and many others. When a contractor obtains a contract to wire a building, he orders the necessary apparatus and supplies and requires them promptly, often finding it necessary to obtain many items upon just a few hours' notice. The jobber must be prepared to deliver these items promptly; he cannot wait to obtain them from the manufacturer; and so he carries a stock in his warehouse. To do this, his capital is invested in stock, he must maintain insurance coverage, pay inventory taxes, and undergo the risk of the product's becoming obsolete or outmoded while still on his hands. Furthermore, he must provide storage space, and the stock must be so arranged as to be readily accessible, so that any item can be identified and taken from stock easily and quickly. A careful record must be kept both of the quantity on hand and the movement from stock, for, on the basis of approximate known delivery time from the manufacturer, orders must be placed in advance so as to provide sufficient stock to meet his purchasers' demands, and yet not too large a quantity, which would add to his storage and inventory costs. The volume of stock may vary on account of anticipated price increases or reductions, price advantages applying to the placing of large orders, and anticipated business activity. In the event that the manufacturer consigns the stock[3] to the jobber, the jobber escapes the tied-up investment in the stock, but must usually stand all or most stocking charges. With all these varying factors, keen business

[3] A consigned stock consists of a quantity of product items placed by the supplier in the hands of a sales outlet or user. The supplier retains title to the stock and has a right at all times to inspect it.

judgment is required to balance the total cost of the stock against ability to serve customers.

The retailer of tractors, who serves a local community, sells direct to the farmer and construction contractor. He carries one of each popular model of tractor in stock for display and demonstration. When one is sold, he orders another from the manufacturer to take its place. In order to meet all service requirements of his purchasers, since tractors are made from a multiplicity of parts and these sometimes fail, this retailer must carry repair or renewal parts which must be furnished the user upon a moment's notice, or be available to his own repair men should he maintain facilities for repair service at his place of business.

We might ask, just what constitutes an economic stock? Certainly, it should have these attributes:

The product must be available at a point where it is to be used.

It must be of the volume and variety to meet the anticipated demands, with some provisions for emergencies.

It should be available complete and ready-packed, usually, for immediate shipment or use.

The product should be of current demand, liquid as to investment.

It must be located so that the minimum effort, time, and expense are required to put it to use.

It must be maintained with the minimum loss in quality and quantity.

The product should be supplemented by a simple, accurate, and complete record showing the kind, quantity, and characteristics of the product stocked.

It must represent a minimum investment.

The intelligent handling of warehouse stocks is a difficult problem, requiring not only an understanding of the simpler technique which has been referred to here, but also the exercising of well-informed judgment relating to business conditions. Market conditions must be thoroughly understood, for, in connection with distribution, stocks must be maintained to meet the market, and, as we have seen, market activity in local districts depends upon a large variety of economic factors. Where we have a manufacturer building duplicate products and carrying these for sale over wide areas, we find these conditions existing:

If stocks are too large, losses occur.

If stocks are too small, business is lost.

If stocks are not properly distributed over the selling area, additional transportation expenses and extensive delays occur to relocate local stock quantities.

If stocks are not of the correct variety to meet the demand, losses occur in the stock itself, and of orders.

To avoid such situations as these, expert judgment must be exercised as to the nature, location, and activity of the market; and these factors must be estimated in advance in order to obtain economic performance.

Equipment Maintenance. Furnishing maintenance service upon a product sold is as much a part of the distribution process as any other function. The object of the seller is that the product, which he furnishes, will continue to operate satisfactorily in the hands of the user. Much as he might desire it to wear out or become inoperative, so that the purchaser would find it necessary to buy again, obviously this would immediately affect the demand for the product and eventually stop its sale. Most technical products, no matter how well made, in time require repair or adjustment, and if such service can be rendered promptly, no matter where the product is in use, it enhances the value of the product and does credit to the supplier, making his product of greater acceptance and, consequently, easier and cheaper to distribute.

Technical repair service is rendered in three ways:

> By the local dealer or agent who sells the product. In such cases, the nature of the service required cannot go beyond the technical talents of the distributor. The distributor of automobile batteries, watches, or radios may furnish the user with replacement equipment for temporary use, while the purchased equipment is being repaired locally or at the factory where it was made.
>
> By the supplier, for often equipment has been sold direct to the user. Such is usually true where the apparatus is of a highly technical nature, and where major repairs are required.
>
> By the user himself, which is usually true where extensive installations are involved, repairs are of a minor nature, and immediate operative service necessary.

Illustrating these three ways, we find, for instance, most retailers of household equipment in a position to render service locally at the point of sale. Paper-making machinery, requiring major repairs and the furnishing of renewal parts, can be efficiently serviced by the original supplier who sends experts, on short notice, direct to the mill. Locomotives, on the other hand, which need frequent repair on account of the severe service encountered, are usually repaired by the railroads in their own repair shops. Repair parts may be supplied by the locomotive builder, or the simpler ones may be made in the railroad shop.

If the local distributor does the repair work, it is often the practice for the manufacturer to train the distributor's repair men at the factory.

Large machinery of a highly technical sort, such as cigarette-making machines, elevators, petroleum refinery equipment, and steam turbines, require skillful engineers supplemented by trained mechanics. Since repair service of a major nature is seldom required, and in the interests of economy must be done quickly, manufacturers devote a specially trained part of their organization to attend to this work exclusively. They also provide, for immediate use, factory renewal parts which are interchangeable with parts that have failed in service.

For a small and inexpensive technical product which is built in quantities following systems of mass production, it is usually found less expensive to replace the item rather than undertake any major repairs upon it. Thus, the plan has become current, in selling, of making liberal price allowances upon old devices.

THE COST OF DISTRIBUTION

Why is it that the ultimate purchaser commonly must pay, for technical products, a price two to five times the actual cost of the product when leaving the production floor? If we consider many popularized commodities and novelties, the difference between the cost of production and the selling price will be found to be in even a much larger ratio.

As we have seen, the processes of manufacture can be witnessed and the individual can usually visualize the costs of material and labor, and, to a lesser extent, the cost of capital, management, and supervision. On the other hand, the total cost of distribution is very difficult to visualize, since various items of cost due to distribution occur at a number of places and are often obscure. Much of it comes through making the product available to the purchaser in the shape and at the place and time required. Most people are amazed at the hign selling price of many products compared with the actual cost of production; and often the assumption is made that large profits are available to the manufacturer. Such assumptions are usually the result of a lack of appreciation of the cost of distribution and the price which must be paid for *availability*.

Let us summarize the kinds of cost that go to make up the total distribution cost of a common product line which reaches the ultimate user through the most circuitous route of distribution, i.e., manufacturer to wholesaler, wholesaler to retailer, retailer to ultimate purchaser. Notice that these items of expense follow closely the functions performed in distribution.

We have the following expenses:

Relating to the product itself:

Packing the product for storage and shipment.

Warehousing the product in the hands of the manufacturer, wholesaler, and retailer.

Transporting the product from manufacturer to wholesaler, from wholesaler to retailer, and from retailer to ultimate user.

Installation of product, where necessary.

Investigating complaints about product.

Rendering maintenance service [4] to support the supplier's guarantee.

Relating to selling the product:

Market research.

Preparing prices and selling data.

Preparing quotations, bids,[5] and agreements.

Contacting customers and obtaining orders.

Preparing orders for manufacture or warehouse shipment.

Relating to sales promotion and customer acceptance:

Advertising, in all its forms.

Preparation and distribution of descriptive and promotional literature, displays, etc.

Relating to the collection of funds:

Credit investigation of prospective purchasers and customers.

Rendering invoices upon products sold and services rendered.

Collecting payments.

The extent of these items of cost depend upon the class of product, methods of distribution, and the market served.

Standardized products, which are no longer subject to periodic design changes and which possess an established customer acceptance, cost less to distribute than those which are continually being altered and improved. If models change, stocks of parts and finished articles carry extensive risks, for depreciation is rapid. Complicated and delicate apparatus often must be packed in an elaborate way, and where such apparatus is shipped to the customer and assembled in his plant, expensive adjustments may be necessary before it can be expected to operate successfully.

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[4] The purchaser of an oil burner or coal stoker may seriously object to the size of the bill that is rendered for the visit of a service man, but the purchaser fails to appreciate the expenses that are necessary to maintain those facilities necessary to render such service promptly at all times.

[5] In most classes of business considered here, only a small percentage of quotations and bids results in orders to the bidder, either owing to the business being placed with a competitor or the purchase being abandoned.

Investigating customer complaints and rendering maintenance services may be a costly item of expense, especially in connection with products which are new and with which the purchaser is not familiar. Purchasers may be overexacting in their requirements, and expenses of this kind often relate to the education of the customer in the proper use and care of the product.

The largest single item in distribution cost upon apparatus is selling expense, including contacting the customer, analyzing his problems, and obtaining the order. Few purchasers realize the cost, to the supplier, of calling upon a customer, and the fact that, in addition to the time and expenses of the individual, there are certain overhead expenses such as maintaining sales offices.

Those primary expenses that make up distribution are salaries, payments to common carriers for transportation, rents and interest on invested capital, and materials. The casual observer sees little or nothing tangible added to the product from the time it leaves the factory door to the time it is placed in use; and yet, how great is the increase in the price of the product!

The fact that distribution costs are usually compared to production costs on a percentage basis should not escape our attention. If a product is built in large quantities, the production cost may become very low, and assuming that there is not a commensurate decrease in distributing cost, the latter expressed in terms of the former may appear extremely high.

CHAPTER XV

THE FUNCTIONS OF ORGANIZED SELLING

SELLING TECHNICAL PRODUCTS

Many technical products, engineered and manufactured with the greatest skill, have become standardized products of regular customer demand. Agricultural equipment and mechanical and electrical apparatus used in the home, office, store, and service shop fall in this group. They are produced and distributed in quantities, and their use and value are broadly recognized. Such articles are sold much in the same way as package goods or merchandise, and are made available through a variety of retail channels existing even in the small business centers. The methods of selling such products have followed closely those of selling consumer goods or commodities. Although the engineer is distinctly concerned with the design and production of such products, and with certain features of market acceptance, he is not directly interested in problems of selling, for these fall within the scope of merchandising. Such products furnish valuable utilities, but in getting them to the user economically, little of the engineer's skill is necessary.

Contrasted to this sort of technical merchandise, we have other technical products used, principally, by all branches of industry, which, in themselves, are of little or no value, but which, when made a part of a process—whether it be the process of mining, manufacture, transportation, or furnishing a public utility—become of great value. Such products cannot be merchandised, because their use depends upon a relationship to other articles and a complete operating process. The skill of the engineer is required not only in the design and manufacture of these products, but also in their sale. This is so, since their successful use is dependent upon proper application in relation to the functioning of a group of products employed in a process. Machinery and equipment used in industry generally serve as the best example of this class of technical products, where engineering skill and selling ability are combined, so that the ultimate purchaser gets the greatest possible value from the products thus furnished.

In this chapter, then, we will not study the principles and organizations required in merchandising, but rather those required in engineer-

ing or technical selling. Most of us are familiar with merchandising methods, for we have daily contact with this type of selling, but selling technical products is of greatest concern to us, as engineers, in the industrial field. Engineering salesmanship has, in recent years, become most important, and requires as much skill, usually, as that required for design, although directed in an entirely different way.

SALES PRINCIPLES

Consumption goods, when bought by the individual customer, are purchased to satisfy wants that come about through the five human senses.

Technical products for industry are largely purchased for the results that can be obtained from them toward creation of goods or services which will lead to utility. Some regard is given to those qualities which satisfy the senses, but only in so far as they contribute to the earning power of the goods purchased. In fact, one might say that the entire interest of the purchaser lies in the ability of the goods that are bought to produce services, and the goods themselves are worthless beyond this point.

In selling, therefore, there is a fundamental difference between the principles involved in selling consumer goods to the individual, and capital goods to the industrial producer. Selling the industrial requires engineering and sales talents which are well qualified to make an economic analysis of production, operation, and equipment problems peculiar to the individual processes involved. These selling talents must be able to support the results of such an analysis by a recommended selection of equipment, the purchase of which can be justified to the management of the company to which they are to be supplied as a sound investment. Thus, in selling we find necessary a combination of technical skill and an ability to reach sound economic conclusions interpreted into the language of the business executive.

Much selling of consumer goods proceeds without serious consideration being given by the supplier to the ability of the purchaser to use the goods purchased, either as to kind or quantity. Although most merchants permit the purchaser certain privileges regarding the exchange or return of goods, the purchaser very largely determines what he will buy, and is encouraged by the seller to buy to "his heart's content," or perhaps to the limit of his financial ability.

This is not true to anywhere near the same degree of the seller and the purchaser of technical equipment that is sold to industry. This is because the seller, if he is to be continuously successful, must take a

very definite interest in the profit-making use to which the purchased products are put. If their use leads to failure in processes or operations, the supplier, being a party to the engineering application of the product, also suffers. Selling technical products to industry, therefore, involves a correct product, and also a correct application,[1] and generally the responsibility for this goes hand in hand with the sale of the product.

WHAT IS SELLING?

As we have seen, selling is one of the major functions of distribution. It is a function of outstanding importance because the supplier, without sales volume based upon purchasers' commitments for products or services, is unable to keep the economic unit intact as a producer. Product selling is supported by suitable products furnished in the required volume at the correct time; production is supported by suitable orders in the required volume to be taken according to delivery schedules that can be met. The selling function brings to the attention of individuals, institutions, and all economic units, the utility of products through their purchase and use. Selling should be looked upon as a creative force,[2] because it stimulates satisfying economic wants, and, in doing so, benefits both the purchaser and the supplier.

Fundamentally, selling is nothing more or less than making it possible for the purchaser to make a selection, obtain, and use goods or services furnished by a supplier, to the end that both benefit by the transaction.

Back in our minds, we may associate with selling the well-dressed, versatile individual, who makes friends easily with everyone, and

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[1] Reference has already been made to the economic function of the consulting engineer. Manufacturers, in their anxiety to sell their products, have taken on a great deal of work of a consulting nature for their prospective and existing customers. Such functions are now included as a part of sales engineering.

[2] An example of sales engineering occurred not long ago. An engineer was trying to sell a popular alloy to a large manufacturer of equipment and machinery. He might easily have continued his visits to the purchasing department of this company and obtained such business as this company could place. However, he proceeded in this way. After a preliminary survey of the products which this purchasing company made, he was convinced that, in many of their products and processes, the alloy he was selling could be used to profitable advantage. With some specific instances at hand, he asked for an appointment with the vice-president in charge of engineering design, and asked his permission to make a complete survey of the company's products with interested designing engineers. The request was granted, and the sales engineer set about helping the design engineers help themselves, and the company they worked for, by showing them where, in certain instances, the characteristics of the product he could furnish would improve the product for which they were responsible. As a result, a substantial volume of regular business was created.

through clever and persistent verbal maneuvering persuades the unsuspecting prospect to buy the product or service that is offered for sale. Such a conception as this relates not only to products and services, but also to ideas, for we come in contact every day with individuals whose plan and procedure are based upon influencing the minds of others through emotional appeal and persuasion. In selling to industry the technical products it requires, there is little place for such a conception, for selling is an economic function, just as essential as production or transportation.

Selling is based upon four fundamental classes of knowledge. They are:

A thorough understanding of the construction and operation of the product to be supplied.

A knowledge of the operations, problems, and processes of the customer.

A familiarity with economic laws as applying to accomplishment in the broad field of industry.

An understanding of human psychology as relating to the individual, his interests, actions, and reactions.

In the utilization of these kinds of knowledge, we find that selling is not an exact science. Although, in most instances, we can foretell with precision the results which will come from following established laws in dealing with materials, we have to deal, in selling, with human factors that cannot be completely evaluated; the reaction of the individual to a given set of conditions cannot be precisely determined.

No attempt will be made here to discuss the art of salesmanship, but we will outline the four major principles upon which successful selling to industry rests:

The purchaser must recognize the supplier as one of good reputation, with ability to supply the product offered in accordance with the requirements of customers and commitments, together with the various forms of service that accompany the product.

There must be a personal contact, based upon respect, faith, and good feeling, between the personnel in the purchaser's organization and the sales representative and his associates.

Through an analysis of the user's problems, by the seller as well as the buyer, both must be convinced of the adequacy of the product to serve the purpose of the user.

The reason for the purchase must be economically sound, and be recognized both by the seller and the purchaser. It must fully justify the expenditure, unless it is of the nature of an experiment, where the full risk is acknowledged beforehand.

The first of these principles requires that the seller develop a favorable reputation through good performance, and through the spoken and written word. The second is based upon sales personnel of high character, pleasing personality, sound judgment, and experience.

The third principle is based upon selling talents that include not only business ability but also skill in the solution of engineering problems relating to the use of the products in a given industry. The fourth requires an appreciation of the value of economic procedure.

In selling, it must be remembered that the purchaser naturally considers the salesman as representative of the supplier, and his impressions of the supplier are formed largely in this way. Since purchasers provide the clientele of the supplier, upon which the supplier depends for an existence, the relationships that exist between sales representatives and purchasers are of prime importance to any economic unit furnishing a product or a service.

WHY IS SELLING NECESSARY?

Selling has often been looked upon as an extra and unnecessary function which increases the cost of a product to the user. Perhaps this is because the product itself is unchanged during the process, and many people know what a product costs to produce and feel that no value is obtained through the added sales expense.

Suppose, though, that the individual had to go to the manufacturer's plant to obtain a new hot-water heater. To what plant would he go? What information would he have upon which to base a logical selection? What are the various merits of heaters? Hence, without selling effort in one phase or another, he would be entirely unable to satisfy his wants without untold effort on his part. Selling has been instrumental in informing the possible purchaser of the nature and utility of an individual product, and also in making it readily available. Even the sales methods of the mail-order house, through catalogue selling, which is the simplest form of selling, require considerable selling expense. The ultimate purchaser pays for being informed, becoming equipped to make a proper selection, and being able to obtain the product readily. But such services are well worth the cost to him and save him expense in buying. Selling, then, is a service and should be considered a part of the cost of the article, just as a manufacturing operation is a part of that cost.

THE SELLING FUNCTIONS

To understand how the selling of a product proceeds in an orderly way, we must understand what the various sales functions are, since selling itself includes a number of kinds of activity all closely related to one another. As we shall see later, these functions extend further than the contact with customers and the obtaining of business, for they reach back into the supplier's own organization and out into the markets of the future. They may be expressed as responsibilities coming under sales management and may be outlined in the following manner:

General Functions[3]

1. Establishing sales policies.
   Just as plans and policies are necessary for operating a railroad system, a factory, or a mine, so are plans and policies necessary in operating a sales organization required to reach a market for a given product.
2. Selecting and developing personnel.
   Sales engineers and other assistants must be obtained, developed, and trained, for one of the greatest assets of any company is the group of men who develop and obtain business.
3. Supervising sales activities.
   Just as an army requires direction, so a group of individuals constituting a sales organization must be directed to obtain a set objective.
4. Establishing prices and other conditions of sale.
   The function which includes pricing policies and the establishing of other conditions relating to terms of sale must be exercised with great care, and understood and followed by all members of the sales organization.

Functions relating to the product

1. Product improvement.
   One objective of the supplier is to furnish saleable products. Since the sales force is in contact with the market, they must be the principal source through which the purchaser's reaction toward the product is obtained, and upon which its adequacy is determined.
2. Product volume.
   Those in charge of production must plan and establish production schedules for the future. Upon those in charge of selling is placed the major responsibility of determining what the market requirements will probably be, as to volume of product necessary for the future.

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[3] Reference: "Marketing Industrial Equipment," Bernard Lester, McGraw-Hill Book Co., Inc., 1935, Chapter VIII.

3. Product stocks.
   Many products supplied industry are furnished from completed stocks held at central or district warehouses. The volume and character of the stocks to be carried are determined by market requirements, interpreted very largely by those in charge of selling.

Functions related to markets

1. Market study.
   We have seen that a study of the market is necessary. This function is a responsibility which falls to those charged with sales, and can be performed by a group of specialists assigned to this work, or by talents engaged for the purpose.
2. Customer contact.
   This is the major function of the individual sales engineer, and it may be supported by experts upon the product or experts upon the class of purchaser under consideration.
3. Market coverage.
   The supplier is faced with the problem of determining the markets which will be reached and those disregarded. Certain territories and certain classes of purchasers may be selected, or an attempt made to reach all who offer sales possibilities.
4. Study of competition.
   All suppliers meet with competition of some kind. Usually such competition is upon products similar in nature, but frequently upon products dissimilar which may serve the same function. No supplier can continue to exist and prosper without obtaining reliable facts regarding competitors' operations and products, and using them wisely.[4]
5. Distribution outlets.
   Many suppliers reach their chosen markets wholly or partially through secondary channels of distribution. These must be carefully selected and served. Their personnel usually requires training, at least regarding the products they sell, and results must be recorded and reviewed.
6. Sales promotion.
   Sales promotion and advertising in its various forms constitute one of the most important sales functions, for the large majority of suppliers.

In relation to sales tools

1. Sales data and literature.
   Upon products to be sold, the sales engineer requires information

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[4] Competition between dissimilar products is well portrayed by the electrical refrigerator and the icebox. In 1934, 16 people used ice to each 4 using electrical refrigeration; in 1938, only 12 used ice to 10 who were using electrical refrigerators. This shows the growth of dissimilar competition. (See *Sales Management*, June 1, 1938, p. 38.)

and data both for his own use in selling, and usually, also, to pass to purchasers for their information and use.

2. Estimates and proposals.

Estimates, plans, and proposals are frequently necessary, and invariably quotations must be made which cover prices, terms of sale, and so on.

Many classes of products or services are sold through the medium of a proposal. This is a written document which outlines what is to be furnished and the conditions under which the supplier will function. When accepted by the purchaser and formally approved by both parties, it becomes a contract calling for performance, and constitutes an order. Such proposals are prepared by the individual sales engineer, or at the head office or district office of the supplier, depending upon the supplier's established rules.

THE SALES ENGINEER

The thoughts and actions of the sales engineer closely follow four lines:

The product he is selling, and its characteristics.

The policies of the company he represents and the conditions of sale.

The operations and processes of the purchaser.

The purchaser as an individual entity, including all persons whose interests relate to the selection and use of the product offered for sale.

Let us study each of these. We find that technical knowledge is required to understand both the product sold and the operations and processes employing it. Problems of an economic nature at once appear vital, because the product has been made as it has to meet an economic need. In the same way, operations and processes have been developed to meet an economic purpose. The policies of the supplier and the conditions of sale under which he disposes of his products are two matters established upon economic principles. Finally, when we consider the purchaser, or any group of individuals who determine whether or not the purchase shall be made, we find persons whose objectives are economic in nature. We also find, however, that since they are persons and not objects, they reason logically, and sometimes illogically, they possess likes and dislikes, and their opinions are affected to a greater or lesser degree by their emotions. Thus, the sales engineer, consciously or unconsciously, employs engineering, economic, and psychological principles, because he deals with technical objects, business objectives, and human beings. In most lines of work these same principles engage our attention, but with the sales engineering ac-

tivity they are all of great importance to achievement of creditable results.

The knowledge of the product by the sales engineer need not be as detailed as that of the engineer who designs it, nor is it necessary for the sales engineer to know all the detailed operations required in its construction. His view of the product must be largely that of the purchaser and user, or all purchasers or users of the class with whom he comes in contact in selling. Since purchasers and users are most interested in the results that come from the use of a product, these must be uppermost in the sales engineer's mind. Technical features which affect the product's application to the service and its continuation in service are those with which the sales engineer must be familiar.

In connection with the selling of a product, the sales engineer must understand the commercial policies of the company he represents toward its customers, and he must be prepared to interpret these clearly to those business concerns with which he comes in contact. He must understand the exact conditions under which his company does business, so that proposals to furnish products or services are clearly defined, as to the responsibilities of the supplier, distributor, purchaser, and ultimate user. Matters of price, guarantee, delivery, and conditions of payment must all be clearly understood.

The sales engineer would be hopelessly lost in his work unless he understood the customers' requirements in connection with the product he sells. For many classes of product this requires an understanding of the processes of the particular industry and the objectives of possible users of the product. Manufacturing today is so highly specialized that each manufacturing process and each operation is highly refined. If the sales engineer selling products to such manufacturers does not understand the equipment in use and the processes and operations performed, with due regard to the economic factors that govern a customer's operations, he is severely handicapped at the start. The sales engineer should be able to bring new ideas to the customer, and do so by means of the technical language and technical terms understood by the customer, for those he is to reach are busy men and have little time to orient the sales engineer calling upon them. One has only to visit a variety of industrial companies to find that each industry has a language all its own, as well as an individual technique. The confidence of the purchaser is immediately strengthened by finding that the sales engineer understands his processes and operations and can talk his language and clearly understand and appreciate his objectives.

In selling, no amount of knowledge upon the product to be sold and the customers' processes and problems is effective in creating business for the supplier, unless this knowledge is presented in a clear and convincing way to the individuals in the customers' organizations who are concerned with the purpose. We have emphasized that companies themselves do not select equipment and purchase it, but rather individuals connected with companies or employed by them in a consulting or purchasing capacity. Sales contacts, therefore, must be with individuals, and, being human, they have an endless variety of human qualities. The sales engineer must be able to determine what individuals really select the products to be purchased.

With the individuals responsible for selecting products identified, the sales engineer must have next an understanding of the peculiar interests of each individual concerned, for these interests will vary. The executive in charge of financial affairs will be interested in capital outlay compared to rate of return, as well as the terms of payment to be met. The operating official will be interested particularly in the place such proposed equipment will assume in a new or existing manufacturing layout, and its effect upon quality and quantity of production, labor relationships, space, and many other factors. The purchaser's engineering talents will scrutinize carefully the technical characteristics of the equipment to be purchased, to make certain that it will exactly meet the needs and be able to continue to operate in a highly efficient way. Understanding the interests of each of these individuals, the sales engineer is required to make his own mind synchronize with the minds of these individuals. Hence, a study and knowledge of personality and human traits are most essential.

Each of us must form conclusions from what we read and what we hear, but in doing so we are influenced by methods of presentation, for our emotions and our reasoning combine to establish ideas which lead to decisions and action. It has been said that the successful salesman must have the power to analyze, visualize, and dramatize, and this to a degree is as essential in the sale of engineering products as in the sale of merchandise. And, although the sales engineer will ultimately fail if he relies largely upon the artifice of persuasive talk, if he is equipped with a clear understanding of his product and the purchaser's processes and problems, he can usually meet with success by clearly presenting his case in a pleasant and convincing manner that builds good will and confidence toward that which he is selling, toward the company he represents, and toward himself.

THE SALES ORGANIZATION

In this country, particularly, we appear to be committed in industry to a policy of aggressive promotion in the sale of our wares, and such activities have become highly competitive. Selling has long since passed the period when it was performed by a group of pleasurable individuals, each blessed to a high degree with personality. Selling has become a very serious undertaking and requires a high degree of skill and a carefully developed organization. The most important single contact a supplier has with the buying public, whose good will and support are essential, is his sales organization. Customers and prospective purchasers form their opinions of the supplier largely from those individuals who represent him. In addition to interpreting the supplier and his products to the purchasing public, the sales organization of the supplier must interpret to the supplier's management the opinions and desires of the purchasing public.

Although sales organizations may be composed of individuals whose operations are widely separated from one another, successful performance requires that these individuals be closely tied together, following the same policies in order to reach the same objectives. They must operate in a systematic way according to budgeted expenses. Such an organization requires an executive head, and where the sales functions are important in a supplier's organization, this head is often an officer in the company.

The sales organizations of various industrial companies vary widely, depending upon the kind of products and services offered for sale, and also the methods chosen by the supplier for their disposal.

For instance, a copper-mining company may sell the ore to a smelting company, little or no selling organization being required. A steam railroad offering its services for the haulage of passengers and freight requires an organization to sell these services and serve its customers that is quite different from that of a manufacturer of instruments for the measurement of temperature, humidity, viscosity, and such. A mill supply house which operates as a territorial distributor for a group of equipment and supply manufacturers is largely a sales organization in itself, and must of necessity be highly organized to perform all the sales functions.

In order to understand the basic principles of organization, we will consider here the type of organization required by a manufacturer of technical products which sells largely to the ultimate purchasers, for in this instance all sales functions are included.

The organization under the leadership of the sales executive usually consists of personnel arranged into two broad groups:

1. Those that regularly devote their major effort to contacting customers in the sale of the supplier's product, commonly called the field sales organization.

2. Those that perform the many functions previously enumerated which are necessary in order to support the sales engineer with products and services that enable him to give customers complete satisfaction. Some of these functions are warehousing, pricing, technical assistance, market study, sales promotion, and advertising.

If a comparison were made between a sales organization and an army, the first group would include those who are organized to engage the enemy, and the second group as those who provide all the requirements of warfare. The sales executive viewing the market, which is to be directly reached by a group of sales engineers, is at once confronted by both problems.

The sales executive, responsible for the distribution of a product or group of products to a widely scattered market, has to organize individuals in such a way as to include all the various sales functions in the most effective and economical way. Certain functions must be performed largely from some central point which is the headquarters of the sales organization, because these functions are fundamental and relate to no local geographic area, or are knit in with other company functional operations such as those relating to design, manufacturing, and financial operations. The functions are these:

Market studies relating to industry or national coverage.

Matters relating to the product—sufficiency as to characteristics, volume, and availability.

Selections and training of personnel, both for headquarters and field sales activities.

Establishing prices and other conditions of sale to be made uniform throughout the sales organization.

Preparing certain estimates and proposals.

Sales promotion and advertising upon products.

The selling function must be performed locally wherever customers and prospective purchasers are located. District sales offices are set up for this purpose which local sales engineers use as their headquarters, operating under the direction of a local territorial manager.

In the assignment of customers and prospective purchasers to individual sales engineers, where the supplier offers a variety of products, the problem arises of either specializing the sales engineer upon one

or a few related products, or allowing him to sell all products to customers in one or a few related industries.

Analyzing the most efficient and economical way of developing business, we find these principles:

> It is desirable for a sales engineer to sell only one line of product, thereby becoming expert in its construction and use.
>
> It is likewise desirable for one sales engineer to sell to only one industry classification, for, in doing so, he becomes expert in the processes and operations involved.
>
> It is also desirable for only one sales engineer to be entirely responsible for the relationships that exist between the supplier and the purchaser, for fixed responsibility is always valuable.
>
> Again, it is desirable for the sales engineer to be located near his customers and prospective purchasers in the interests of economy of operation and prompt attention to needs of customers.

If the student will study these four limiting factors, he will see that to comply with all of them is well-nigh economically impossible, and a compromise is at once necessary in almost all instances because the market is not sufficiently dense to justify such a high degree of specialization, and the products made by one company often extend over a wide variety.[5]

PROMOTING THE SALE OF TECHNICAL PRODUCTS

Sales promotion is that phase of distribution which deals with creating an acceptance for the product or service furnished. As we have seen, our civilization is characterized by invention and production, and, to support these extensive accomplishments, efforts have been directed to develop and maintain purchasing markets. The purchaser is usually not in search of products to buy, but rather the producer is extending ingenuity and skill to inform and influence him to buy. In an

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[5] The following illustrates a typical compromise of customer assignment to sales engineers. A manufacturer builds four products rather closely related—speed reducers, pulleys, gears, and line shafting with fittings—all of which fall in the group of transmission equipment. One district sales office is located in Detroit covering the state of Michigan and several counties in northwestern Ohio. Five sales engineers operate in this territory with one district manager, who devotes a large share of his time to assisting sales engineers. One sales engineer has a territory consisting of the counties located in Ohio, two others divide the state of Michigan, a fourth has the Detroit area as his territory, and a fifth, also operating in the Detroit area, devotes his entire time to the automobile industry. Owing to the large demand from the automobile industry, one can understand the advantage of assigning one sales engineer to this industry alone. (See "Marketing Industrial Equipment," Bernard Lester, McGraw-Hill Book Co., Inc., New York, 1935, p. 176.)

effort to attract the purchaser to the product or service which is offered, and to familiarize him with its uses and advantages, all sorts of devices have been employed. The supplier combines these in what he terms a sales promotional program.

In any such program, four fundamental kinds of knowledge are necessary:

> An understanding of the characteristics and merits of the product that is furnished.
>
> A knowledge of the present and possible uses for the product.
>
> An acquaintance with the motives and interests of the purchaser and those who use the product.
>
> An appreciation and understanding of human characteristics and reactions, and the course of reasoning followed in reaching a decision to purchase the particular product that is offered.

Sales promotion is distinctly an economic function. Whereas manufacturing creates a product for which a need exists, through the use of materials, labor, and a variety of indirect expenses, so sales promotion, through publicity and advertising in a variety of forms, creates customer acceptance, which decreases the cost of distribution by making selling easier. Its economic value, however, does not exist unless the product has merit and meets the uses and needs of the purchaser. The first and second classes of knowledge named above deal with material things and processes of procedure. They can be considered objectively, analyzed minutely, and their various characteristics evaluated, since physical laws govern them. When we consider the third and fourth factors, however, we enter the realm of psychology, for we deal with the operations of the human mind as it functions in the world of business.

If we consider that the product possesses merit—for sales promotion is wasted in gaining acceptance for a product without merit—and that there is a definite need for it, we can proceed to consider those factors which determine the opinion that exists or can be created regarding the product, by those who have use for it.

The law of diminishing returns applies to sales promotional effort, for it is quite possible for an enterprise to extend such efforts to the point where the cost fails to support the gain in resulting business volume. Consequently, sales management not only must be alert to the quality of sales promotional effort to see that expenditure yields the greatest possible return, but also must exercise control over the extent of this effort. No exact method has been discovered for measuring the results of sales promotional effort and expenses, and the eco-

nomic return is largely based upon judgment developed from experience.

Perception. When we first see a gasoline engine, it appears as an object of shape and color. Upon further examination, it is found to respond in a certain way to touch, hearing, and smell, and our *perception* of this object becomes more complete as we add other sensations to the original sensation of sight. We become able to identify such an engine even though it is quite remote, because we have attained a good perception of it. Finally, because of previous experiences, we can perceive it when only a symbol is used to signify it, which may be the spoken word, a picture, or a printed word.

Perception, therefore, is an awareness of objects present, and, when the object is represented by some symbol, ideas are awakened in the mind regarding this absent object, based on previous sensations. Sales promotion is largely pursued through symbols—printed words and illustrations, so used as to emphasize the advantages of the thing symbolized, hence acting as a real aid to perception.

Apperception. We cannot look on the mind as we look upon a machine which functions under a given set of conditions precisely in one way, for the mind is not a bundle of faculties. Rather is it a unit which feels, remembers, reasons, decides, and wills, and during its conscious existence it exercises itself along any of these different directions with varying degrees of intensity. At no one time does any one function take complete occupancy, for in every function of the mind, memory, suggestion, perception, as well as many other individual functions, play their part.

Apperception is the process of the mind by which, through what has been retained during the past, it interprets and evaluates a new experience. It extends beyond perception, for it includes an action of the mind by which perceptions and ideas are clear and distinct and also receive attention in regard to their relationship to other objects and events gathered from previous experiences. In viewing an object, in addition to the action of the object on the mind, there is through apperception a reaction of the mind on the object. Knowledge is increased therefore by an addition to the accumulated store of experience gathered by the individual person, each new experience being gained in relation to previous experiences. Individual minds are not able to create entirely new ideas, but rather add new elements or combinations. The mind itself enlarges its stock in trade principally from old elements, and gradually builds up the ability to interpret all that the senses encounter as life goes on.

Promoting Sales through Symbols. Originally trade was based upon an ability of the purchaser to see the goods, and satisfy all his senses; today purchasing is done largely through symbols because it is impractical for the purchaser to make a complete inspection of the product. In the field of mechanized products, it is impossible for the buyer in many instances to witness the product in the performance of its functions, unless products are purchased which duplicate those used or in service. Products have increased in number and become more complicated in construction, so that visualization has become more difficult. The creation of a mental image, by means of symbols, has become an art, and the principles underlying them and their use are a science. The expert use of these symbols as a means of promoting ideas, to which reactions favorable to the supplier are sought, constitutes the field of advertising. The technique of advertising must be built up through a knowledge of the human mind not only in its ability to perceive and apperceive, but also in its susceptibility to suggestion as well as the factors that command the mind's attention and determine its will to act in a desired direction.

The Objects of Advertising. It is customary to think that the purpose of advertising is to assist in selling the product or service. Although this is fundamentally the object, the immediate objective may be of a quite different nature, as will be apparent from the following summary of the functions of advertising relating to new or established technical products.

The functions of advertising may be:

1. To announce to a market the availability of a new product or form of service. Advertising usually makes it possible for the supplier, in making this announcement, to:

   Reach purchasers and prospective users in mass at low cost.

   Reach a particular class of market without waste of expense on others.

   Reach those at a distance or in out-of-the-way places, where personal solicitation would be difficult and costly.

2. To state the characteristics of the product in a clear and concise way, according to the language of the purchaser and user, thus creating acceptance independently of the sales engineer's efforts, yet in a correlated way.

3. To show the purchaser the manner in which the product can be used in furthering the economic processes engaging him, so that his business can be conducted on a basis of greater return to ownership, management, and employee.

4. To familiarize the purchaser with the supplier as an organization equipped to serve, thus establishing in his mind confidence and trust.

5. To correct untruthful statements or impressions which have become current regarding the supplier's organization, services, or products.

6. To locate or assist in locating able and desired sales outlets which may distribute the products or services locally, or, if such already exist, to strengthen their position in relation to the market.

7. To establish in the minds of the supplier's own distributing organization a greater recognition of their responsibilities and further their respect and confidence for the products or services they distribute.

"Salesmen and Advertising—There Are 16 Ways That Advertising Helps Salesmen to Sell More Goods at Less Expense," *Iron Age*, December 3, 1936, p. 90.

Advertising and Sales Promotion. Many of us may look upon advertising as a matter of taking a certain display space in a specific publication for a definite number of issues, and using this space to the greatest advantage. Such a conception is incorrect. It is as unreasonable as considering only the signal system in the building of a railroad. As the signal system of a railroad is only one part of a communication system, and that in turn is but a part of the railroad system, so page advertising is only one part of advertising, which in turn is only one part of a sales promotional plan. Advertising is but one group of tools for carrying out a sales promotional program, and one tool of advertising is page space in publications.

A sound sales promotional program to assist in the sale of a product to an existing or potential market is made up of a variety of activities calculated to inform and inspire the supplier's organization engaged in selling, and the market which is to be served. Advertising is that part of a sales promotional program which, largely through symbols, endeavors to inform the market of the existence and merits of the product and its supplier, and create in the minds of those individuals who constitute the market a desire for experiencing the benefits which come from possession and use of the product. What forms advertising may take, whether it be page space in publications, individual letters to prospects, display material, or what not, are determined by an intelligent analysis of the actions and reactions of the minds of those who buy or influence buying.

References

J. F. Apsey, Jr., "Functions of Advertising Media," *Industrial Marketing*, May, 1938, p. 23.

"Advertising Plans for '39," *Industrial Marketing*, January, 1939, p. 19.

The Technique of Advertising. Advertising, as we have seen, deals with a given product or service which can be put to some useful purpose. The product, for instance, must be capable of definition as to its construction, operation, and use. As possible profitable users, we have a market which, as we have observed, may extend from the individual purchaser buying for his home, to the largest corporation, which purchases for the purpose of carrying on a successful enterprise. In any event, the purchasers are human beings who possess habitual mental traits and emotions formed from instinct and experience, and these govern their opinions and actions. These traits may be influenced and changed, so that the resulting reactions to a set of conditions may, in time, alter.

The completed product offered for the user may be termed static, but the individual who has an interest in its possession, or can be so interested owing to his economic position, may be termed mobile. His reactions toward the product itself and its supplier can be made to change, and these changes may end in his will to purchase and use, or the will to do otherwise. The supplier, then, in advertising deals with a static product, and mobile minds, in an endeavor to increase the regard of the mind for the product, and lead that mind to a decision favorable to the purchase of the product. Obviously, various degrees of ethics and honesty may be followed in the process. Ultimate profit and stability of the supplier can come only through truthful inferences and statements regarding the product, and a complete regard for the success and well-being of the purchaser after a purchase has been made, and the product put to use.

The technique of advertising equipment and apparatus used in industry differs from that of promoting products purchased for individual consumption, where the emotional appeal is the greatest. Industry buys for use and service in various processes, and the fancy of the individual purchaser is seldom catered to. Since buying decisions are based upon the ability of the product purchased to perform an economic function under specific technical conditions, the interests of the purchaser do not relate so much to the product itself as to the use of it. His conclusion to purchase is arrived at by a process of reasoning, based upon facts and the experiences of others.

"Agencies Analyze Advertising," *Industrial Marketing*, January, 1938, p. 23.
PRESCOTT WINKLEY, "Sell Ideas—Not Products," *Industrial Marketing*, February, 1938, p. 11.

KEITH J. EVANS, "Coordinating Sales and Advertising," *Industrial Marketing*, February, 1938, p. 21.

"American Blower Campaign Built Around Reader's Interests," *Industrial Marketing*, January, 1939, p. 26.

The Results of Advertising. The results of efficient sales promotion consist of increased sales and decreased selling expense. As advertising is an effort the effect of which depends upon repetition and continuity—owing to the characteristics of the human mind as well as seasonal activities of purchasers—the element of time plays an important part. Seeds sown today may bring fruit many years hence. Again, advertising being only one tool in selling, any gain in increased sales volume or decreased selling expense may be due to other forms of effort than those of advertising. The results of advertising are most difficult to determine, and also the relation between the quantity of advertising effort and the quantity of sales results or degree of selling economy.[6]

These variables, combined with the fact that advertising is a highly specialized form of service often purchased from independently operating companies whose income depends upon the volume of work done, have in the past provided a happy hunting ground for the promoter of advertising schemes of a questionable character.

The Economy of Advertising. Advertising can be destructive just as it can be constructive in creating an acceptance for a product. It can be destructive if it gives incorrect information about the product or service, or creates incorrect impressions in regard to what these will do when put to use. It may be employed to so large an extent that it creates a desire in the minds of the purchasing public out of proportion to the ability of the product to serve. The value of advertising depends, then, upon its quality in conveying information vividly and correctly to those who may be interested. This requires that it be directed at a given group of possible purchasers, which can be done only by selecting the means best fitted to this group.

The question is frequently asked, what amount of gross income should be devoted to advertising technical products? This question cannot be answered intelligently without an understanding of the character of the product, the degree of acceptance already existing both for the trade name of the supplier and for the product itself, and the extent and buying habits of the market. Obviously, for a new product which must be introduced, sales promotion and advertis-

[6] Reference: "How We Evaluate Results," D. C. Miner, *Industrial Marketing*, February, 1938, p. 9.

ing are necessary beyond that required for a product which is recognized by an established market. Apparatus which enters the home or must reach the individual purchaser and depends upon popular appeal, requires a greater degree of advertising effort than factory equipment having little emotional appeal.

Advertising in its various forms has been popularly regarded as benefiting only the supplier. This is not true, for it has to a large extent been instructive to the possible user of the product by calling to his attention what is available, and stimulating his mind toward the solution of his problems and the betterment of his operations.

THE COST OF SELLING

When a manufacturer produces a product such as a mechanical speed reducer consisting of gear wheels, shafts, bearings, and a housing to contain them, you can see the various parts formed and machined, assembled together, tested, painted, and packed for shipment. Some conception can be formed of the value of the materials which are purchased, of the time and labor required to perform the necessary physical operations, and it can be realized that to provide for manufacture many expenses are necessary even in addition to production equipment.

In distribution, however, the expenses incurred cannot be easily visualized, for they are disconnected and do not relate to a physical change in the product. Selling expenses are only a share of distribution expenses, and the salesman's salary and traveling expenses are only a share of selling expense—for sales supervision, clerical help, sales office rental and maintenance are some of the other more important items which must be included.

The cost of calling upon customers when reduced to figures is, to most suppliers, alarmingly high,[7] particularly where only a few calls per day can be made. It is much the same as the cost per mile to operate an automobile where the car is little used, and depreciation, interest on the investment, garage cost, etc., must all be included; or the cost per game of golf for the club member who plays infrequently. The high cost of selling emphasizes how important it is that the work of the salesman be laid out with a view to economical customer coverage.

The cost of selling engineering products has a definite relation to competition. Where competition is severe and the number of com-

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[7] One manufacturer of industrial apparatus estimates that the average call, upon the average customer, costs the company $5.

petitors is large, selling costs are usually high. Business has been developed very largely on the principle that competition is the life of trade, and it is true that the principle of competition fosters initiative and stimulates the producer in an attempt to supply better and lower-priced products. On the other hand, when it is unrestrained by rules based upon ethics and sound business practice, it tends to increase selling costs and consequently the price the user ultimately pays for the product.[8]

Speaking in general terms, selling costs are inherently high:

Where the product or service offered is new to the buying public.

Where the make of product is new, i.e., where a supplier undertakes to offer a product which he has not formerly made and sold.

Where possible purchasers are few and far between.

Where a large number of similar products or services are offered by competitors and extra selling effort is required.

Where extensive sales engineering service is required to determine the exact requirements of the purchaser.

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[8] Products which are standardized, and upon which the buying public is well informed, are much more subject to price stabilization than services which depend upon engineering and installation skill. For instance, let us consider air-conditioning service for a business establishment. A restaurant owner desires to equip his dining rooms with this form of service. Eight contractors are called on to bid upon the installation. Each sends a sales engineer to the premises, and analyses are made of the local conditions, estimates are made, proposals are prepared and bids are furnished. Drawings, perhaps, are prepared, and subcontractors estimate upon the duct systems, plumbing, and electrical wiring. Each contractor is put to considerable expense in this work, and only one is the successful bidder. The burden of such expenses ultimately must be borne by all suppliers and be paid for by all purchasers.

CHAPTER XVI

PRICE AND PRICING POLICIES

WHAT IS PRICE?

Value is the basis of our economic thinking. As we view the available products and services about us, we see that they possess varying values. These values come through the ability of these products and services to fulfill an immediate want, as in the case of commodities such as foods which answer human desires, or durable goods such as machinery and equipment which an industrial manufacturer desires in order to produce other goods or services again to fulfill human wants. Price problems on the latter class of goods and services particularly interest the engineer.

New products and services are continually entering our civilization as items of increasing or lessening value. Fresh air, light, and pure water have always been items of value, but measured according to our common denominator of price, as people have come to live together in towns and cities, these items, which many years ago were looked upon as free, have become more difficult to obtain and hence of greater value. Many attics and junk yards are filled with household products or industrial products which, today, have little value except as antiques representative of an earlier period. Values applying to products used by industry today depend upon:

The suitability of the product to meet the need.

The characteristics of the product relating to its usefulness in performing a service.

The availability of the product in the quantity and at the time and place desired.

The cost of the product.

Price is our common measure of value, and is expressed in what we call money or currency. As currency should have value in itself, we have used copper, silver and gold as money, for these materials have value in themselves. We speak of the "gold standard," taking the metal gold of defined quality by which to measure the currency value of other materials. In order to economize in the use of the

metal, and for greater convenience, we use engraved slips of paper which represent current values, retaining the metal, itself, in storage as value to support the paper. The paper has value because of the fact that it may be redeemed in the form of the metal. Such a practice, however, is subject to the danger of governments issuing more paper than is supported by metal, and there is thus the questionable practice of deflating the currency, or creating forms of currency which have no actual supporting value.

THE PRICE SYSTEM

This nation has progressed along agricultural and industrial lines under a system by which we have allowed economic values to govern trade and industry. The control of production to meet and adjust itself to human wants has been largely free from monopoly and artificial authority. It has been contended that any substitute through artificial means of price control, rather than control by economic values, affects adversely the stability of our own currency and detracts from the force of industrial initiative. Similar results, many people have felt, would come from a control of production by any overriding authority. Our price system, then, has been built upon the economic supply and demand of a given product, and a form of currency based upon gold as a metal. It is free to change independent of the authority of any governing body.

From a practical point of view, for products and services which can be furnished efficiently by only one supplier to a group of consumers, and where these consumers require these products and services as necessities of everyday life, public regulation of price has become current practice for the protection of the consumer. The extent and degree to which price regulation will apply has been continually broadening, and constitutes a matter of public policy upon which opinions differ.

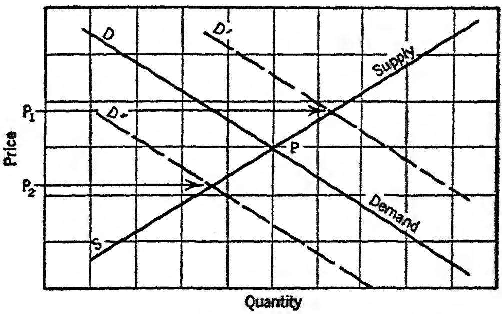
SUPPLY AND DEMAND

Under conditions of free competition, we are inclined to explain the price system by the statement that price levels are determined by the law of supply and demand. The operation of this law, however, is not an altogether simple one, and it requires further attention.

Under competitive conditions, the point which determines market prices is that point where the bid of the buyer with the least desire to buy equals the offer of the seller with the least desire to sell, so that the quantity of goods which changes hands will be the largest possible without loss. We see, then, that the strength of demand depends upon

the strength of desire and purchasing power of the buyer; and the level of price set up by the potential seller depends largely upon the seller's costs and ability to hold the product until desired prices can be obtained.

Prices will tend to be high when the desire of buyers and their ability to buy are strong. Prices will tend to be low when sellers desire to sell and cannot afford to continue to hold the goods. Prices, however, can never be lower than the supplier will accept or greater than the potential buyer will give. Bids and offers, according to this law, become equalized, and we arrive at a point where the price becomes temporarily fixed or in equilibrium and exchange takes place. Under the law of supply and demand, if there is no interference, production



1. The effect of variations in *demand* upon the price of a product, when the supply remains constant.

and consumption are adjusted at a price level which is reasonable and fair.

The two curves shown in Figs. 1 and 2 are familiar ones in economics and show the theoretical workings of the law of supply and demand. This law, in simple terms, merely states that price varies directly with demand and inversely with the supply of a product. In these curves, points P_1 show the price created by increased demand or increased supply while points P_2 are prices caused by a decreased demand or supply. Point P is merely an assumed reference point from which we can observe the variations in price with changes in demand and supply. In Fig. 1, we observe that, if supply is constant and demand is increased, price likewise increases, while if demand decreases, prices also come down. On the other hand, in Fig. 2, we see that, if demand is constant, an increased supply means lower prices and a decreased supply indicates higher prices. These

are, of course, highly theoretical, and the student must remember that both supply and demand vary. The reactions of both variations will be reflected in price. Also, the fact mentioned previously must be considered, namely, that the price will never be lower than the supplier

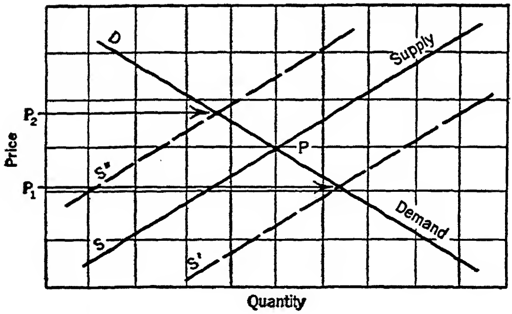


FIGURE 2. The effect of variations in *supply* upon the price of a product, when the demand remains constant.

will accept nor greater than the potential buyer will give; further, the "elasticity" of supply and demand or the slope of the supply and demand curves has much to do with the magnitude of the changes in price with each change in supply or demand.

PRICE EVALUATION

From the viewpoint of price, engineering products—which are largely capital goods, as contrasted to commodities which are largely perishable goods—require an analysis on the part of the student from other angles than that of supply and demand.

Commodities are made and distributed for prompt consumption, and their value exists through their ability to satisfy an immediate demand. The quality of foods, for instance, can be quickly determined and comparisons drawn between grades and brands. Since commodities are graded and standardized and a high degree of common knowledge exists in regard to their characteristic features, we find that they are influenced more directly by the simple law of supply and demand.

The value of most engineering products comes from their ability to produce other goods, often commodities, or render needed services. Often the value of engineering products depends upon a highly specialized degree of usefulness. The value of various kinds of bearings, for instance, used in steel mill machinery can be determined only by test,

and such tests must be made under a variety of circumstances and conditions and may require an extended period of time. After such experience has been gained, and not until then, is the value firmly established in the minds of the purchaser and user. These same bearings, however, might be found unsuitable for use as a part of paper-making machinery, because conditions of application and use differ. We see therefore that the value of such items depends not only upon the relationship they bear to other items with which they may be used, but also upon processes which often are complicated and surrounded by a wealth of specialized experience.

The evening gown may be of attractive, durable, and expensive material, but yet be worthless through changes which have taken place in style. Last year's model of a dough mixer may, however, possess as great a value as one produced this year, assuming that no marked improvements have been made which increase its usefulness.

In the case of engineering products, usefulness and price evaluations are closely associated with those who create and supply the product. Prompt delivery, erection, or installation by hands skilled with the product and its use, and the availability of spare parts, as well as other conditions and facilities, may regulate price to a marked degree.

PRICE DETERMINATION

The engineer is particularly interested in the sequence of reasoning leading up to price determination in relation to a product and a market. Price is a vital matter when deciding to develop a new product that is to be made for sale, and also in the modification and improvement of a product that already is in existence.

Fundamentally, the matter of first consideration is the market in terms of the utility of the product, the value of its utility, and the desire of the market for it. Matters of design and production are, within limitations, under the control of the builder, but matters of market are largely beyond his control. All the calculations of the designer must be based upon market prices, whether these are estimated or existent.

From a practical standpoint, the manufacturer of products that are made by engineering skill encounters a number of factors in determining the selling price for the product.

1. That which attracts his attention first is the cost of producing the product in the quantities that the market can absorb with a reasonable distributing expense. As we have seen, due regard must be given to all items of cost, including those capital expenses which have gone into the development of the product, and the establishing of a

manufacturing and distributing set-up. Since the manufacturer is not only a producer but also a consumer, due regard must be given to the probable variations in the cost of commodities and services which are purchased, and their effect upon the total cost of production.

2. Competition, unless selling prices are fixed, to a large degree determines the selling price, and tends to force prices down to a point where the greatest ingenuity is required on the part of the manufacturer to maintain a fair profit on his invested capital. Competition exists not only from other suppliers who furnish similiar products, but also from suppliers who furnish products which in some degree or other will perform similar services. Thus, we see competition between positive pressure compressors and multi-stage turbine blowers over a certain range of service, and similar rivalry between metal-working tools which cut and those which grind for certain required work.

3. The utility of the product is an important factor in determining the selling price. Not many years ago the portable electric drill was perfected to the point where it obtained universal acceptance wherever drilling operations were repeatedly required. Its cost to the purchaser exceeded many times the cost of the hand drill, yet it eliminated labor, hastened manufacture and repair, and improved working conditions.

The broom was the only common means of cleaning the home, office, and shop thirty-five years ago. It could be purchased for a small amount. The vacuum cleaner was invented and exploited, and in a few years it found an enormous market at a comparatively fabulous price, because its superiority to the broom for regular cleaning operations was so pronounced. Similar comparisons could be made between the old icebox and the modern mechanical refrigerator, or the wash board and the electric washing machine. Since engineering products are sold to provide a service, and in industry are purchased with regard to the quality and quantity of the service, the price paid is directly related to the earning power of the service.

4. The reputation of the producer, as interpreted in the quality of the product furnished or services, such as prompt delivery and maintenance, may command a higher price. Many manufacturers of heavier machinery make a practice of having their engineers present when equipment is received by purchasers and installed, to make sure that nothing goes wrong and that the apparatus works satisfactorily. Again, service shops may be established at local points, to render prompt and expert maintenance service. Such factors as these may command from the purchaser a higher selling price upon the product sold than can be demanded by competitors who do not furnish such services.

CAUSES FOR PRICE DIFFERENTIALS

Though it is common to think that the price for which a technical product sells is determined by such fundamental factors as cost, supply and demand, and competition, this is not entirely true.[1] Temporary fluctuations in such factors as these may be entirely disregarded by the manufacturer and supplier. Stability in price is desirable to the manufacturer, distributor, and purchaser.

From a practical point of view, the supplier in carrying on his business, encounters a number of conditions relating to those fundamental factors just named, that cause price variations to exist. These conditions concern the product made or service rendered and the characteristics of the market. The commonest causes for price variation are outlined below:

Condition of Design Regarding Obsolescence. With style an increasing factor in production and sale, old types, models, and styles are considered less desirable than new, and are therefore often sold at relatively lower price levels.[2]

On the other hand, should old types, models, and styles be demanded after existing stocks had become depleted and regular production discontinued, the selling price undoubtedly would be higher than for current designs.[3]

Time of Completion. On a construction contract or the supplying of equipment, time of completion or delivery may be an important factor, and a bonus may apply to completion within a specified limit of time. A delay beyond a stipulated time may also be subject to a penalty in the form of price decrease.

Quantity purchases may be a reason for price variations, in which case the number of units bought, or the total dollar volume the purchaser orders at one time, determines the price that applies. Further price variations may be contingent upon the time the order will be delivered—for instance, upon completion or within a specified time. Also, if the supplier furnishes a variety of products, the variety of the prod-

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[1] We can readily see what confusion would exist if the price of any article continually altered according to the cost of those products and services which are required in its manufacture.

[2] We are all acquainted with this in the automobile industry, for example. Before new models arrive, if stocks of old models are still available, they are often sold at reduced prices.

[3] For instance, an accident breaks the driving gear of a large hammer which has been in service for fifteen years. The hammer manufacturer no longer builds this model. This item is supplied at a high price, because manufacturing information and patterns must be taken from storage and a single unit must be made.

ucts selected as well as the total order value may cause price variations.

Engineering and maintenance service applying to the product, such as supervising its installation, may be the reason for higher prices than are charged for products that do not require services of this nature. For many classes of machinery and equipment, the supplier, in order to provide a satisfactory installation, will insist upon supplying—and charging for—supervisory engineering service.

Form of guarantee may sometimes affect the price, for if the purchaser assumes the risk in the selection, application, and performance of the product—buying the product "as is"—the supplier avoids a risk and consequently can furnish it at a price differential. Most reputable manufacturers insist upon a standard guarantee applying to new products which they sell, however, for their reputation is at stake, and price differentials of this kind usually prevail only in connection with certain classes of second-hand equipment suppliers.

Special equipment usually commands a relatively higher price than standard equipment; such items are often produced singly or in small quantities, so that the cost of making and handling is greater.

Methods of packing and shipping may alter price levels. For instance, a purchaser may desire and be willing to pay more for 100 pieces of apparatus packed in individual cartons than the same quantity packed in one large crate. A higher price may apply for packing for export shipment than for domestic shipment, too.

Competition, as has been pointed out before, is a ruling factor in pricing engineering products. This may be from competitors who furnish substantially the same kinds and grades of equipment, or it may come from quite different sources, e.g., a different kind or class of equipment or different product.[4] Tile glass, for instance, might be looked upon as a competitor of lighting fixtures and electric lamps. Certain classes of hoisting equipment might be competitive with certain classes of conveying equipment, or certain classes of grinding machinery might be competitive for special production operations with certain classes of cutting machinery. For particular kinds of service, the acetylene welder competes with the electric welder. Industry abounds in competitive equipment, and the introduction of one class of equipment or product may cause price changes in others.

The buying power of purchasers relating to the amount of their

[4] The manufacturer of aluminum has been accused of holding a monopolistic position as a supplier of this material, yet aluminum has a great many competitors in the form of other materials.

purchases of various classifications of products, or the total size of their annual purchases has also been used as a basis of price variation by the supplier.

Terms of payment for some classes of products and in some classes of business may provide for price variations. Many jobbers and even retailers may allow, for instance, a discount of say 2 per cent for payment within ten days.

Location of the purchaser[5] may for some classes of product determine whether the purchaser pays the transportation charges from point of manufacture to his door or not, which causes a variation in the prices customers pay for the product. Many producers and suppliers deliver free, absorbing this expense in their cost, or arbitrarily establish free delivery points which are acknowledged as such by the industry of which they are a part.

From a study of these causes for price variation, the engineer will see how complicated the price policies of a supplier become, and what a wide variety of factors influence prices that are made where the supplier sells directly to the user. Further complications arise, as we shall see, if the product passes through the hands of a reseller, and he must receive compensation for his services as a distributor.

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[5] The "Pittsburgh Plus" plan of pricing steel has caused much controversy and litigation, and illustrates one of the most complex problems in pricing policy. As the steel industry grew, Pittsburgh became its largest producing point, and for years steel prices were based upon Pittsburgh as a delivery point, no matter where the steel was made. Thus, a purchaser, in Chicago, of steel made in Chicago mills, was required to pay the base price plus freight charges from Pittsburgh.

As other producing points grew, consumers at such points as Chicago complained greatly about paying freight from Pittsburgh on steel produced in their own vicinity, and they insisted on a base price *at the mill.* As a result, the Federal Trade Commission issued a "cease and desist" order against the "Pittsburgh Plus" system of pricing in September, 1924.

Out of this grew a multiple basing point system in which basing points were established at most of the main steel producing and shipping centers, so that buyers paid only the freight from their nearest basing point. Prices at each point were not necessarily those at Pittsburgh, but were dependent upon the necessity for competition with Pittsburgh delivered prices and ability to supply the demand from local mills.

By no means has this problem been settled, however. The order of 1924 was not enforced by any court action, and as recently as March, 1938, attempts were made to make this 14-year-old order "final." Numerous other controversies have arisen recently on pricing at multiple points. In July, 1938, elimination of differentials on Pittsburgh at various basing points and new basing points were announced.

References: "Efforts to Enforce Abandoned Order Again Raise Basing Point Issue," *Steel,* May 22, 1938, p. 17; "Price Relationships Disrupted," *Steel,* July 4, 1938, p. 15; "Consumers Find New Competitive Conditions in Steel Set-up," *Steel,* July 11, 1938, p. 15.

ESTABLISHING PRICE LEVELS

Establishing the correct and equitable selling price upon most popular commodities may be a relatively simple matter, but when we approach the more complicated technical products, the problem often becomes quite involved.

Price structures upon such products as automobiles, farm machinery, radios, household appliances, which are sold to the individual, though they may be distributed through local resale outlets, have become simplified and standardized. The individual usually does not purchase in quantities, his requirements are for immediate delivery, and he buys for cash or according to an established deferred payment plan. The industrial buyer, however, may buy singly or in large quantities; the order may include a variety of standardized stock items or special "made to order" items; delivery may be extended over a period of time; erection or installation services may be included; and many other variables may enter into the transaction which add a variety of complications affecting the selling price.

We have seen, too, that many manufacturers reach a part or all of their market through resale channels, and in so doing encounter the problem of resale discounts which are intended to provide to the distributor a reasonable amount to defray the cost of selling, which may include a variety of functions, plus a fair profit.

Let us examine the problems in pricing encountered by a manufacturer of centrifugal pumps sold widely to industry. This product is highly specialized as to its function, but possible purchasers exist in almost every industry classification. Furthermore, smaller local purchasers are usually reached through various distributors. Below are some of the problems that we might well encounter in pricing the equipment of this pump manufacturer. It is assumed that this product is being sold direct to the ultimate user.

Selling Direct to the Ultimate User

Classes of ultimate purchasers:

Let us consider the classes of ultimate purchasers. Should certain classes of these be entitled to lower prices than others on the same equipment? For instance, should the steam railroads, public utilities, paper, steel, and textile manufacturers, etc., all be able to purchase corresponding types and sizes of pumps at the same price, or should there be a differential in price level depending upon the class of purchaser?

Quantity of duplicate units:

Suppose that a coal-mining company is opening up a new mine and requires for mine drainage a lot of 100 duplicate standard units, delivery to be accepted as soon as they become available. Should this purchaser obtain a lower price per pump upon this lot than the purchaser of a single pump?

Suppose that the program of mine drainage is to proceed slowly over a period of 10 months, and the pumps are desired only at the rate of 10 per month. Obviously, the mine owner desires to delay capital expenditure, and avoid storage costs. Should the same price apply for extended delivery as would apply when all pumps are shipped at one time or as soon as completed?

Quantity of non-duplicate units:

Another coal mine finds that a solution to its drainage problem requires this same number of pumps, but six different pump sizes will be required. Should the same price level apply as if all pumps were duplicates?

Volume of annual purchases:

A large steel manufacturing company, in analyzing past purchases, which are made only to meet periodic needs, finds that the year before last $25,000 worth of pumps were bought from this supplier, and that during the last year the purchases had totaled $50,000. In view of this past volume of purchases, is this buyer entitled to a lower price in his buying?

Location of purchaser:

This pump builder, being located in Massachusetts, sells a pump to a cotton mill located in the builder's own town. A similar purchase is made by a cotton mill in Georgia. The latter complains because he must pay the freight on the pump which in this case is a considerable item, as he is a keen competitor of the cotton mill that is located in the pump builder's town. Is his complaint justified?

Bonus and penalty:

A city is buying a large pump as an addition to the city water works. Delivery must be made within three months from the time the order is placed, and a decreased risk to the city is obtained by an earlier delivery if possible. In placing the order, the city specifies that a penalty of $25 per day will apply for every day delivery is delayed. The pump builder insists that a corresponding bonus of $25 per day apply if delivery is made earlier than the three months. Is the pump builder justified in his contention?

Price guarantee:

A paper manufacturer is putting up a new mill, which will require one year to complete. Several pumps are required to be installed during the year. The mill officials agree to place the order with the pump builder at once provided delivery will be extended throughout the year,

and the price applying will be that which exists at the time the order is placed. Is the pump builder justified in accepting such a proposition?

Problems such as these are encountered by every supplier of technical products purchased by the industrial market. Every successful supplier must establish a price policy calculated to meet all conditions of purchase. It must be definite, fair, and easily interpreted by individual buyers. It must be legal, and comply with all federal and other statutes.

The "open price" policy, by which producers publish their prices and their price policies governing sales, is increasing in popularity. This practice, in itself, has done much toward price stabilization, because each purchaser can tell what other purchasers pay for the product, and, with prices and price schedules made public, there is less tendency on the part of the purchaser to attempt to beat down quoted prices.

Establishing price levels for services such as furnishing electricity, water, gas, communication, and transportation, which by their nature are largely monopolistic, present problems that are extremely complicated. In but few instances can true comparisons be made between existing companies, because usually only one supplier exists, and in various locations expense factors may differ to a marked degree. Also, the engineer is immediately confronted by problems of evaluation of existing property investments, because all these suppliers must, of necessity, employ physical facilities that are costly, in order to furnish adequate service.

The student will do well to review the causes for price differentials which have just been discussed relating to products, and see wherein these various factors apply to the various forms of public service.

Price differentials, for instance, in the use of electricity, may depend upon:

Classes of use, i.e., domestic or industrial use, or heating and cooking.

Quantity of electricity consumed over a given period.

Demand charge, that is, a variable rate structure based upon the fixed and variable charges on the equipment necessary to serve a customer, and varying with his load factor.

Time when current is consumed—during off-peak load periods, for instance.

Peculiarity of demand, as by a factory subscriber with large inductive load which, in turn, affects adversely the public utility system, and indirectly other consumers.

Public utility services are, by no means, without competition. Railroads compete with air lines, buses, and automobiles for passenger traffic, and trucks, pipelines, and waterways for freight; electricity must compete with gas and other fuels for cooking; telephone companies compete with telegraph service; and so on.

SELLING TO RESALE CHANNELS OF DISTRIBUTION

We have seen that many technical products are distributed through resale channels such as wholesalers, retailers, contractors, and other equipment builders. Some resale distributors act as selling agents for the producer; others purchase the product and sell it in turn. Price systems on a given product are based upon the price applying to the ultimate purchaser, from which discounts are given applying to various selling agents or purchasers who buy for resale. Thus, the manufacturer endeavors to set up a "discount schedule" applying to various classes of selling agents and purchasers who buy for resale. Such discounts constitute a form of compensation which is set in accordance with the form of service rendered as an element in the chain of distribution.

Since those who resell may perform a wide variety of services, there is consequently a wide range in the amount of compensation applying, or the discount from the retail price to which they are entitled. The most simple form of resale outlet—which simply solicits orders for the producer, and performs no additional functions such as carrying a stock, representing the producer exclusively, exploiting the product by advertising and displays, or providing maintenance for the product sold—would obviously receive the smallest compensation. Those who perform the functions named, and others which might be added, would receive a greater discount, which would vary with the forms of distributing services rendered.

WHAT IS A FAIR PRICE?

The question of what is a fair selling price for a product is a subject which continually leads to argument. The American industrial system would answer this by saying that a fair price for an engineering product is one which, based upon efficient manufacture and distribution, provides a reasonable profit to the owners of the economic unit producing this product, after labor and management have received a fair reward for work they do. Active competition is relied upon to

continue, and our civilization fulfill its destiny of an ever-growing service to the needs of mankind."[4]

This may appear to the young engineer as a well-worded idealistic preachment. However, if we observe seriously what is happening in this country, as well as in many others, even though our viewpoint is selfish in the extreme for our own safety and good, we must project our thoughts and efforts into matters that deal with the social and economic welfare of all classes of people.

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SUCCESS AND FAILURE

There are many definitions of success, and the popular conception of success changes as economic and social conditions alter. With our own definition of value based upon what has been termed the "American system," success may be applied to the individual who creates value, and in proportion to the value created will his success be measured. As has been pointed out, "value" includes much more than "profit," and it seems evident that in the future the accumulation of wealth will to a lesser extent be a measure of success.

Various studies made of groups of engineering graduates in different industrial establishments indicate that most failures to satisfy the employer thoroughly have not been due to lack of technical knowl-

[4] From "The Engineer in a Changing World," Ralph E. Flanders, *Electrical Engineering*, August, 1937, p. 940.

edge or willingness to work, but rather to a lack of ability to establish and maintain satisfactory relationships with fellow employees and to fit in harmoniously with a group of aggressive workers in a practical way. Such conclusions should point to the wisdom of the individual's making a closer study of the development of his own personal traits and establishing habits of conduct which will increase his usefulness. In doing so, however, one should guard against the dangers of becoming too self-centered and too self-conscious. The universe starts with the individual himself. His accomplishments come through development in the world beyond himself.

One of our prominent and successful engineers, whose accomplishments have come from a balance of technical skill and ability to cooperate with others, has itemized those qualities most desired by able and sound management. They are these: [5]

> Integrity—based upon a high degree of honesty and sincerity.
>
> Dependability—as to word and prompt action.
>
> Determination—or the ability to start and carry through.
>
> Resourcefulness—which includes devising ideas and methods beyond the limits of the beaten track, and is closely allied to initiative.
>
> Forcefulness—a characteristic which rests upon conviction and expression.
>
> Adaptability—or the ability to fit into a variety of conditions in a harmonious way.
>
> Cooperativeness—the ability to work with others including those of greater and less responsibility.
>
> Diplomacy—which is based upon an understanding and appreciation of the viewpoints of others.
>
> Friendliness—for a thousand times as much can be accomplished through an attitude that is pleasant in place of one that is antagonistic.
>
> Tolerance—in the sense that the opinions of others must be respected, and the viewpoint must not be narrow or prejudiced.
>
> Knowledge—or fact information, as considered here, upon principles, objects, and processes.

Education in terms of academic training carries with it responsibility. Twenty-five years ago, the college graduate was an exceptional individual in the rank and file of industry. By those who had not had similar advantages, he was often considered an intellectual aristocrat, and on this account his path was often disagreeable before his ability and worth were seen and recognized by his associates. Today, this is

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[5] Reference: See "The Selection and Training of Engineers," A. M. MacCutcheon, *Electrical Engineering*, September, 1937, p. 1085.

true to a much lesser extent. Nevertheless, industry does not look kindly upon the young engineer or college man who is impressed with his own importance, yet industry recognizes the value of the individual who has confidence in himself. The young engineer may soon come in contact with men who are much older than he is, and who have accumulated a wealth of practical experience. Especially is this true in the manufacturing and construction fields. Such men perhaps learned many of the reactions to physical laws by experience whereas the engineer has learned them only in theory. They may feel that the approach to theory should be from experience in practice, and fail to realize the value of theoretical knowledge as a basis for practical procedure. The young engineer will do well to respect and listen to such older men as these, for they can do much to help or retard his progress.

Industrial management looks on the young technically trained employee as an individual with great possibilities. His immediate earning power, however, is relatively very small, and often his employer must invest in him an amount equal to or more than his first year's salary in expensive training before he justifies his income. The management of most companies watches the young engineer's progress much more closely than he realizes. Often special tasks are given him in order to observe his reaction; if it is favorable, his responsibilities increase. Management has pointed out in many cases that the young engineer expects too rapid a promotion and is too anxious for advancement in salary. What should interest the graduate most is what his position may be in a period of ten or fifteen years. No structure can be a success unless it is supported by an adequate foundation.

Time is one of the most important elements in most engineering projects. In preparing an estimate upon a structure or apparatus design that must be submitted on a certain day and hour, the whole effort may be wasted for the estimate is useless unless it is prepared within the allotted time and presented prior to the closing date. The engineer to be successful must train himself in meeting scheduled performance.

Any preachment upon the necessity of hard work may appear hackneyed, yet success in any profession is obtained only through almost unlimited hours of toil. To the individual who has chosen the field he enjoys, such effort brings great satisfaction. If one is not in the line of work he enjoys, a change should be made at the earliest opportunity.

Reference

Frank L. Eidmann, "The Young Engineer's First Years in Industry, *Electrical Engineering,* May, 1938, p. 206.

THE ENGINEER AND HIS PROFESSION[6]

A large share of graduate engineers start working for a corporation engaged in the production of products or services of a technical nature. In doing so, they quickly become absorbed in a particular phase of their employer's activities, in the success of an individual interest, and in an interest in the industry of which the company for which they work is a part. As we have seen in all industrial activities, there has taken place a continually greater specialization of effort, and to be useful, the individual must focus his efforts as a part of a creative system.

Without deploring the need for or wisdom of specialization, the narrowing of the trail we follow has its disadvantages as well as its advantages. It has been jokingly said that the engineer proceeds to know more and more about less and less until he knows everything about nothing, while the commercial representative, who is called upon to have a smattering of knowledge on many subjects, knows less and less about more and more until he knows nothing about everything.

The engineer, finding himself a part of a company, an industry, and a profession, is, however, in a position where he may not only focus his efforts, but also broaden his horizon of thought and action through an interest in the activities and progress of his profession.

Fortunately, in this country, professional societies in the field of engineering have been organized and active for a long time. They have been founded and led by men of broad vision. In recent years a greater degree of their attention has been paid to the relations of the engineer to leading economic and social problems. The variety of their interests has increased. They serve as a meeting ground for the discussion of technical subjects relating to construction projects, the design of apparatus, and its application to industry, and also its systems of operation and the practical economic results from these. They present to the engineer an opportunity during his career for following technical progress in his chosen field and also an opportunity for self-expression. The young engineer should investigate these engineering societies to which he is eligible for membership, branches of which exist in most commercial centers.

To summarize the most important ways in which the young engineer

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[6] References: "The Place of the Engineer in Modern Life," Harvey N. Davis, *Mechanical Engineering,* December, 1937, p. 893; "The Engineering Profession," Gano Dunn, *Electrical Engineering,* October, 1937, p. 1235; "Hall-Marks of the Engineer," N. W. Dougherty, *Civil Engineering,* April, 1937, p. 253; "Why Be an Engineer?" *Power,* July, 1938, p. 45 (357).

may grow and be of greater service to society, perhaps the following may be helpful:

Development of technical skill. Besides performing the duties assigned to him, the young engineer will do well to:

Widen his knowledge through reading technical articles appearing in professional journals and current technical magazines.

Attempt soon to write an article himself, and develop a style which is clear and direct.

Make the acquaintance of other and more experienced engineers in the line of work which interests him, and find opportunities for contact and discussion.

Attend local meetings of technical societies and take an active part in their progress. Learn to talk before a group of people with confidence when definite ideas and convictions are worth expressing.

Development of interest in social, political and economic matters:

Take an interest in local and national government activities, by following daily events through the press; develop and test sound opinions.

Join a club or society, preferably one which provides outdoor athletic advantages, where one can meet and know people in other professions and lines of business.

Read consistently some books and articles which deal with social and economic problems.

As time passes, take an interest in younger persons following lines of work similar to one's own, or those with less opportunity, so as to develop the habit of "giving" as well as "getting."

The reader may wonder how the individual has time to take part in all such activities as these, but he will discover, as he advances, that almost invariably men with the greatest responsibility find time for the greatest activity, because they learn how to direct their efforts in work, as well as recreation, to the best advantage. There are few more pitiable sights than an individual who has grown old in the harness of a particular job and finds himself without other interests or avocation.

Outside interests serve as a broadening influence upon the engineer, because in these human contacts breadth of view is developed. Although social activities are important, the greatest reward to the individual often comes from a service that is of benefit to the community or to a group of citizens who need assistance.

No more significant statement of the future for the engineer appears than the predictions of President Harvey N. Davis of the Ameri-

can Society of Mechanical Engineers in his address entitled "The Engineer of the Future," which was delivered at the spring meeting of the A. S. M. E. in Los Angeles on March 25, 1938. It follows:

> The Engineer of the future is going to make tremendous strides in this matter of studying human beings and . . . when he does so he will become the industrial manager of the world. This subject of management is in reality a branch of engineering, at least in this country . . . where in the last 40 years engineering has been always developing work which has been managed exclusively by engineers. Management is one of the great opportunities lying before the young engineering man; and some of the fields of management are so highly developed that we can give courses and write textbooks about them. . . .
>
> Of course there are a lot of problems in this field . . . for instance, the very important problems of industrial relations between employer and employee. There is no group of men in industry today that is closer to and understands better the problems of both the employee and the employer than do the engineers. They can look upon the problems of both groups objectively.—*Electrical Engineering,* July, 1938, p. 280.

THE POWER OF AN IDEA

In concluding our discussion of the engineer as a citizen, one is struck with the power of ideas. What has been accomplished through new ideas in the physical field can similarly be accomplished in the field of human relationships. Only a fraction of the thought which has been devoted to physical concepts and relationships has been devoted to social concepts and relationships during the last thirty years of progressive mechanization. A single idea in the development of wire communication, and also wireless communication, has startled the world, and has inspired thought which has led to a large number of ideas which have made accomplishment possible.[7] Ideas such as these have

[7] In 1875, two men were working with various apparatus in the attic of an old building in Boston, Massachusetts, in an attempt to develop a system of multiplex telegraphy. Each had an instrument of his own in separate rooms of the attic. One of the men chanced to notice that the vibration of a reed before an electromagnet in the other room caused a similar vibration in the instrument before him. *The idea was born.* That man was Alexander Graham Bell, and that observation marked the start of the development of the telephone system that is ours today. And from this basic idea, thousands upon thousands of ideas have been born until we have the almost perfect telephonic and radio communication of today.

Along this same line of thought, Major Squier in 1910-11 first successfully used multiplex telephony by means of carrier currents. His *idea* has today made it possible to hold five separate telephone communications over a single pair of wires at the same time, or send 24 simultaneous telegraph messages, plus one

been creative in changing our civilization. They possess drama—the drama of physical accomplishment—and this drama has stimulated the minds of a large group of people, in a similar way, to discover principles and create new objects of value.

We have seen that the very creation of these principles and objectives has introduced perplexities of a social nature that threaten to upset the order of things, and bring human misery in place of human happiness. Our economic problems, combined with our social problems, are daily proving to be of greater importance than formerly. New ideas in the control of industry and its creations are becoming increasingly necessary, and also new ideas in human organizations and their operation. These, more than anything else, are necessary today if our civilization is to continue and improve. Man is the most difficult object of study known, not only because of the complicated nature of the individual, but also because desires and emotions are constantly clouding reason. With greater knowledge of human beings, the engineer with his factual training and power to reason logically can play a very large part in creating those *ideas* that will direct our path better.

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telephone conversation, over a single pair of wires. And that idea is still working today, for a recent announcement tells us that the Western Union Company has successfully combined the *idea* of the "electric organ" and multiplex telegraphy to send 96 messages at once over a single circuit by superimposing the messages on tone pitches, 300 cycles apart in frequency, of the electric organ's mechanism or tone generators.

CHAPTER XVIII

ECONOMIC STUDIES

Throughout this book an attempt has been made to emphasize the economic aspects of any problem or subject that might be at hand. We have seen how inescapable these aspects are—how they must be watched and heeded if men and enterprises are to be successful, how failure to recognize just one economic phase of a problem may make the solution of that problem weak and inaccurate. It is with these thoughts in mind that the following series of economic studies are prepared.

It is not the intention of these examples to develop the ability of the student as a mathematician or statistician, but instead to stimulate thought along the economic line of reasoning. Some of the problems become definitely "will it pay?" questions, adaptable to an arithmetic solution. On the other hand, the economy of the suggested change or selection may be well hidden in judgment factors and unmeasurables so that the solution results only from carefully weighing every factor—tangible and intangible—and being certain that no important ones have been left unrecognized. Such problems daily confront the engineer in industry, and to start their solutions "from scratch" is usually a necessity, for data and certainties such as the design engineer has available to him are not plentiful in considering economic problems here.

The importance of economic thinking is well expressed by Lawrence E. Frost of Commonwealth Edison, when he said, concerning the design of an engine, that:[1] "the question 'how efficient can we make it?' must be coupled with the question 'how efficient can we afford to make it?'" It is our responsibility to find the true economic factors of each problem. The form in which each example is presented here should by no means be taken as a standard, but the approach to each solution should be from the most logical viewpoint, and all influencing factors should be included and evaluated.

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[1] From "Engineering Economy Page," *Journal of Engineering Education*, April, 1938, p. 585.

There is natural rivalry in the world of commerce and trade between various products and various forms of service. Since engineering products are sold on the basis of the service they render, various producers advance the merits of those methods which employ their products. There is no intention, in presenting the various studies which follow, of promoting one product or service in preference to another. The only purpose of these studies is to illustrate typical problems which exist and the methods applicable in approaching an economic solution.

Grateful appreciation is expressed to those individuals and companies who have furnished information used in the preparation of these studies. In many instances such material has been reworded to meet the needs of the book.

STUDY 1

A PROBLEM IN AIR CONDITIONING

A large factory uses an air-conditioning unit of some 650-ton capacity in conditioning some special process and storage rooms of the plant, as well as the offices. Previously, it has been the practice to purchase from the city the condenser cooling water used in this large installation, but, with a rise in water rates, it has been found that this water will cost the company some $12,000 per year.

Engineers of the plant propose to cease buying condenser cooling water and to substitute cooling towers costing $50,000, by which condenser water can be cooled and recirculated constantly. The plant management somewhat objects to the excessive investment required, but is willing to consider the idea if the engineers can show a return of but 6 per cent on the investment. It is found that the interest on this investment will be 5½ per cent, and depreciation is to be calculated on a straight-line sinking-fund basis of an estimated equipment life of 20 years.

The engineers, in making up a cost analysis, use data of a similar installation elsewhere. They find, especially in the maintenance of the towers, that expenses are somewhat higher than anticipated. It was found, for instance, that on account of the make-up of the water available, there is great danger of impurities being drawn into the towers along with the air, where they would enter this water, form corrosive acids, and be destructive to the pumps, condensers, etc. This discovery made necessary the provision for constant treatment and frequent chemical analysis of the water used at a cost of $450 per year. Added to this were the regular maintenance costs of inspection, cleaning, etc.,

which, from estimates based on similar installations, will cost $1600 per year.

Careful estimation was made of the power costs of fan and pump motors, and this was concluded to be $1350 for all such equipment per year. The "make-up" water, or that water necessary for circulation and which must be purchased, is estimated at an annual cost of $450. Incidental costs added another $100 yearly to the cost of cooling towers.

With all these costs, will it still be found cheaper to install the $50,000 cooling towers or should purchased water be continued? The detailed cost analysis takes the following proportions:

COOLING TOWER COSTS PER YEAR

Power (fan and pump motors)	$1,350
Maintenance	1,600
Water analysis and treatment	450
Cost of makeup water purchased	450
Interest on investment ($5\frac{1}{2}\% \times \$50,000$)	2,750
Depreciation ($\$50,000 \div 20$)	2,500
Incidental	100
Total cooling tower costs per year	$9,200

The cost of purchased water is $12,000 yearly, and this represents the entire cost by this method, since no further investment is needed in equipment, etc. The savings per year, by using cooling towers rather than purchasing cooling water, are shown by the cost analysis to be:

$$\$12,000 - \$9,200 = \$2,800 \text{ per year}$$

This saving, however, is only 5.6 per cent of the $50,000 investment and hence falls short of the required 6 per cent set up by management. The engineers, firmly convinced that water rates would go still higher and that the cooling-tower idea was fundamentally better, set about to recheck their estimates but could find no mistake or saving that they might have overlooked. However, one of the crew of engineers suddenly hit upon the idea of making the cooling towers do multiple duty. It was found, eventually, that, by using the water from the cooling towers for several steam turbine condensers and three Diesel engines in another department, besides supplying the air-conditioning condenser cooling water, an additional saving of $1800 per year resulted. This, added to the calculated $2800 of the air-conditioning unit alone, brought total savings to $4600 yearly, or a return of 9.2 per cent on the investment. The management approved the project and the towers went in. This example shows how, by overlooking an entirely remote source of expense or saving, an economic cost analysis may be misleading and suggestive of unsound procedure.

STUDY 2

METHODS OF APPLYING FINISHES IN PRODUCTION PROCESSES

The ways in which production costs are reduced and production rates increased are many, but of much interest is the advancement made in applying finishes to articles in regular line production. It goes without saying that each advancement is economically justifiable or it would not have been adopted, but a few of the newer developments in this phase of production provide an interesting study of the economics of production.

In early production processes, the old method of brushing was used. But, as production processes speeded up and as higher efficiencies were demanded, a new method of applying a finish that could keep pace with other production processes was demanded by manufacturers. The spray system of painting was the answer.

In a study of the factors which will determine the economic advantages of spray painting vs. hand brush painting in a specific case where metal parts, for instance, are to be finished, such factors as these stand out as important:

Number and continuity of parts to be painted.
Labor costs.
Investment and depreciation of spraying booths, exhaust fans, air compressors, spray guns and accessories.
Space requirements for spraying equipment.
Transportation costs to and from spray booths.
Savings in paint and materials.
Quality and uniformity of work required.
Flexibility as to paint colors.
Specific markings required, such as decorations.

Every industry which uses spray painting equipment does so to cut costs as well as to improve the finishes on products. This improvement in appearance leads to the reduction of sales resistance, to larger sales, and to greater production, all of which revert back to lower cost of production. It has been conservatively estimated that today at least 85 per cent of all the products of industry requiring a surface finish are given that finish by means of the spray gun. Spray finishing is so generally accepted as the only means of product coating and finishing that there is no longer any comparison with older methods.

Even though the spray has so completely outmoded older finishing methods in speed and quality of work, industry is today no more satisfied with its finishing speed than it is with the speed of its other production operations. The cry is faster, faster; and the producers of

spray painting and finishing equipment are answering by the development of machines and equipment that are as far beyond the capacity of the hand-operated spray gun as the spray gun was beyond the brush.

Production finishing can now be done by machines in automatic operation very much the same as other manufacturing processes. A rotary spray finishing machine, for instance, will do as many as 3600 small, light-weight articles an hour. The product to be coated or finished is loaded on one end of the machine and comes out finished at the other end. Such a machine can be set into the production line, receive the article mechanically from the last manufacturing process, and discharge it into wrapping and packing machines. A few of the many articles which are coated or finished by means of rotary spray machines of this type are electric-light bulbs, golf balls, bottles, jars, automobile parts, electrical and radio parts, spools, novelties, telephone parts, ceramic ware, toys, and innumerable other small, light-weight articles.

Larger products in sheet, roll, or panel form, with curved or flat surfaces, are automatically sprayed at a rate of 240 square feet per minute in a machine of another type, known as a planetary crank-type spray coating machine. A few of its uses are automatically spraying products such as hides, imitation leather, wall coverings, wall board, floor coverings, blackboards, paper, fabric, shingles, glass, and tile. Furthermore, hardly a day passes but that some manufacturer installs a machine which has been specially designed and built to meet the particular requirements of his finishing operation—to speed up his production, lower his costs, increase his profit.

In many plants where the volume of painting or finishing justifies the installation of the necessary equipment, paint is piped over a plant just as one might pipe water. Faster finishing, better control, improved working conditions, cleaner housekeeping, and finally lower costs, are the result. It is a long way from the gravity bucket of the early spray finishing system to the modern paint-circulating system. Both feed paint to the spray gun, but modern manufacturing has progressed much since the days of the gravity bucket. Paint handling costs have been reduced in many instances and output increased in automobile body and refrigerator plants and in other manufacturing establishments by means of such paint-circulating systems—to say nothing of their other mechanical advantages.

Faster finishing, more spraying, and new kinds of finishing materials have necessitated new and improved finishing-room exhaust systems. The water wash spray booth has come forward to take care of these changing conditions. It cuts down the frequency of cleaning,

avoids complaints of neighbors, improves working conditions, minimizes fire hazards, cuts costs, and thereby increases profits.

Information courtesy: The DeVilbiss Company, Toledo, Ohio.

STUDY 3

A PROBLEM IN PLANT LAYOUT

In Chapter X, plant and production layout was studied in its economic aspects. Mention was made there of the value of process flow charts and flow diagrams. We will reproduce, here, the charts and diagrams of an actual layout, before and after revision, which clearly bring out the savings made by revising the old and uneconomical plan of production.

The particular company involved was confronted with the need for

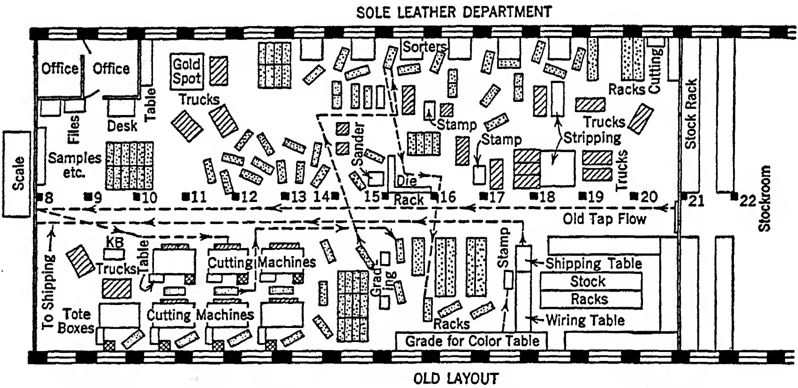

FIGURE 1. Process flow diagram of the old manufacturing layout.

more room in a department manufacturing leather taps [1] for the shoe trade. It was desired to keep the department within its present space limitations so as not to take up space from some other department in the plant.

The first step in solving this problem was to draw up a process flow diagram of the old layout, as shown by Fig. 1. It is quite evident by looking at this flow diagram that a great deal of handling and travel in the old layout was unnecessary. To determine how much such handling could be eliminated, the department was next laid out in miniature, by means of templets for all equipment, and a study was

[1] Leather taps are made from a section of the hide called a "bend."

made of each step in the manufacturing process for various arrangements. Always in mind was the desirability of an ultimate arrangement in which the steps of processing should follow one another in a steady forward flow.

As the plan for the new layout developed, the introduction of simple mechanical conveyors, chutes, and proper work-receiving benches which would reduce handling and transportation and speed production, was seen to be advisable. Furthermore, in the proposed layout, owing to elimination of back-tracking and hence rehandling and rack storage, an opportunity was seen whereby 75 out of 80 existing cumbersome stock racks could be discarded. Also, several production machines were no longer needed, under the new plan, to carry out present or even increasing levels of production. Figure 2 shows the final selected layout by which these advantages were gained. A study of the old and new flow diagrams, and the comparative process flow charts [2] shown

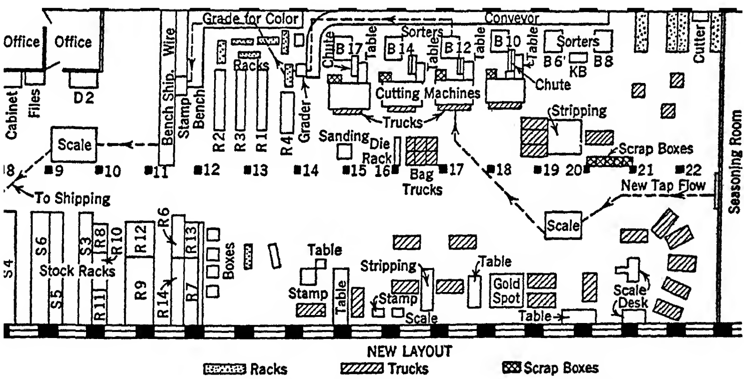

FIGURE 2. Process flow diagram of the new manufacturing layout.

in Fig. 3, clearly indicates the new layout to be a distinct advance in economic production.

As the flow charts will show, in revising its productive layout, this company reduced the number of operations from 63 to 39 in the leather taps department, and reduced travel from 1460 feet to 464 feet for each 100 bends. To execute this revision cost $1900, from which investment one year's savings were $2700. Production in the department increased 25 per cent with the same number of man-hours as in the old layout. By a change in procedure, under the new plan, in

[2] Refer to footnote 13, Chapter X, page 261, in using the symbols make up the process flow charts of Fig. 3.

PROCESS CHART
SOLE LEATHER DEPARTMENT

Old Process

Travel		
	▽	Bends in stock rack for seasoning
160	(M)	Get truck and go to storage
	(1)	Load 100 bends on truck
205	(K)	Take load to scale
	(2)	Weigh
70	(K)	Take load to cutting machine
	(3)	Take bends from truck, Pile on mach. tray
	(4)	Place one bend on cutting block
	(5)	Cut taps
	(6)	Place taps in rack
	▽	Repeat until rack is loaded
20	(K)	Move load to grading machine
20	(M)	Return to cutting machine
10	(M)	Obtain empty rack and repeat as above
	(7)	Take taps from rack
	[8]	Grade taps
	(9)	Take taps from grader
	(10)	Place in empty rack
	▽	Repeat until rack is loaded
30	(K)	Move loaded rack to sorters
30	(M)	Return to grading machine
	(11)	Take taps from rack
	(12)	Pile on sorting bench
	◇13	Sort taps
	(14)	Place taps in rack on sorting bench
	▽	Repeat until rack is loaded
	(15)	Take taps from rack on bench
	(16)	Place in empty truck rack
	▽	Repeat until bench rack is empty
45	(K)	Move rack to put-up bench
45	(M)	Return to sorting
	(17)	Take taps from rack
	▽	Place on make-up bench
	[18]	Make up into dozens
	(19)	Place at stamp
	(20)	Stamp
	(21)	Wire in dozens
25	(M)	Go to box storage
25	(M)	Return with boxes to packing bench
	(22)	Place dozen taps in box
	(23)	Pile for labeling
	(24)	Label
	(25)	Stamp size and grade
	(26)	Pile boxes on truck
160	(E)	Take load to shipping room
	▽	Storage
10	(K)	Move truck to packing bench
	(27)	Take packing list from load
25	(M)	Walk to order file
	(28)	Compare packing list with order
25	(M)	Return to packing bench
	(29)	Take boxes from truck, lay on bench
	(30)	Place boxes in cartons
	(31)	Seal cartons
	(32)	Mark name and destination
25	(M)	Go for wiring machine
25	(M)	Return to packing bench
	(33)	Wire cartons
	(34)	Place on truck
15	(K)	Take load to scales
	(35)	Weigh
50	(K)	Take load to shipping storage
	(36)	Empty load on floor
60	(M)	Return to packing bench
25	(M)	Take sole leather truck to elevator
25	(M)	Return to packing bench
	(E)	Elevator to third floor
10	(M)	Pull empty truck from elevator
	▽	Storage outside elevator
160	(M)	Sole leather man walks to storage
	(37)	Obtain truck
160	(M)	Return to packing bench
1460		

63 Operations and moves
1460 Ft. travel

New Process

Travel		
	▽	Bends in stock rack for seasoning
90	(K)	Get truck and go to storage
	(1)	Load 100 bends on truck
45	(K)	Take load to scale
	(2)	Weigh
20	(K)	Take load to cutting machine
	(3)	Take bends from truck, pile on mach. tray
	(4)	Place one bend on cutting block
	(5)	Cut taps
	(6)	Place in chute by machine
	(7)	Take taps from chute
	◇8	Sort taps
	(9)	Place taps in individual grade racks
	▽	Repeat until rack is loaded
	(10)	Place loaded rack on conveyor
	(G)	Sorter to grader
	(11)	Take taps from rack on conveyor
	[12]	Grade taps
	(13)	Take taps from grader
	(14)	Place in empty rack
	▽	Repeat until rack is loaded
5	(M)	Push rack to put-up bench
	(15)	Take taps from rack
	▽	Place on make-up bench
	[16]	Make up into dozens
	(17)	Place at stamp
	(18)	Stamp taps
	(19)	Wire in dozens
20	(M)	Go to box storage
20	(M)	Return with boxes to packing bench
	(20)	Place dozen taps in box
	(21)	Label
	(22)	Stamp size and grade
	(23)	Place in shipping cartons
	(24)	Seal cartons
	(25)	Mark name and destination
	(26)	Wire cartons
	(27)	Place cartons on truck
8	(K)	Pull load to scales
	(28)	Weigh
128	(E)	Truck to shipping storage
	(29)	Empty load on floor
	▽	Storage
128	(E)	Return to sole leather
464		

39 Operations and moves
464 Ft. travel

	Old way	New way
Operations	63	39
Feet of travel	1460	464
Cost of change	$1900	
Annual saving	$2700	

Figure 3

which products are made ready for shipment immediately, instead of being placed only in factory containers and being sent to the shipping room, a further saving of 60 per cent in shipping costs was effected.

This example illustrates not only the economies of straight-line production, but also the importance of flow diagrams and charts in determining economical production layouts.

> *Example and figures from "Pay-Off on New Layout—150 Per Cent," William T. Connors,* Factory Management and Maintenance, *July, 1937, p. 57.*

STUDY 4

DESIGN OF A DEEP WELL SUBMERSIBLE PUMP

Liquids are now obtained from deep wells by means of either centrifugal or plunger pumps. These pumps are suspended in the well, the centrifugal type of pump being driven by a revolving shaft, and the plunger pump being driven by a reciprocating shaft.

Often these pumps, owing to the depth of the well, require several hundred feet of shafting. Engineers have for many years been studying the possibility of designing an electric motor and a pump built together, as a unit, suitable for lowering into the well and operating in a submerged position. Some designs of submersible pumps of this kind are available today commercially. Some interesting technical and economic problems are involved, in an endeavor to locate the power-producing unit immediately adjacent to the unit utilizing the power, and thus decrease the initial investment and operating expense.

Although shaft-driven deep-well pumps have been in operation for many years, giving excellent satisfaction, the elimination of the shaft is desirable, particularly from the viewpoint of cost and the space it takes up in the vertical well piping.

The design problems are complicated for these reasons:

1. Space diameter is small, for the pumping unit must be able to fit into a 6- or 8-inch hole. The motor, in order to obtain the necessary power, must be constructed of small diameter and considerable length, and this applies also to the pump itself. Being submerged, however, it is subjected to a pronounced cooling effect from the liquid, which is advantageous.
2. The motor must be so constructed that water or other liquids cannot get into it.
3. The conductors, extending from the top of the well to the pump, must be supported and insulated.

4. The unit must be easily withdrawn from the well hole when desired.
5. Self-lubrication for an indefinite period is necessary.

The principal economic problems involved are:

1. Comparative initial cost of submersible unit, with its support and conductors, against the cost of the conventional pumping unit plus shafting and electrically driven power head mounted at the mouth of the well.
2. Comparative operating efficiencies and operating costs.
3. Advantages accruing to the submersible pump from the increased cross-sectional area of the hole available for the transmission of the liquid owing to the elimination of the shafting.
4. Risks involved because of the great difficulty in determining impending trouble with the pumping unit owing to its remote location, and thus making it hard to correct trouble before failure takes place.
5. Comparative life of the two kinds of equipment.
6. Ease with which provision can be made to meet changing underground liquid levels with either class of equipment.

STUDY 5

ADOPTION OF METAL SPRAYING PROCESS IN REBUILDING WORN PARTS

A certain plant is debating whether it would be economically justifiable to purchase and operate equipment for the metal-spraying process of building up worn metal parts. Throughout the plant are various places in which this process might be substituted for the method of reconditioning now employed, if the metal-spraying process can be proved to be satisfactory by saving on reconditioning jobs over present methods.

One of the first jobs considered is that of worn armature shafts of direct-current motors. The replacement of these shafts is laborious and costly. Such replacements cost all the way from \$125 to \$500 and involve stripping from the shaft, commutators, and core, and rewinding and replacing the commutators. By the use of metal spraying, worn journals can be built up and remachined without the removal of any part of the windings or commutators and at a cost of but \$30 to \$40 for the bigger machines. Motors ranging from 5 to 150 hp. can be so reconditioned. It would appear that, with savings in labor and convenience, metal spraying would most profitably fit in on such work. But can this equipment and process be used successfully for other jobs?

Another use was found for metal-spraying in connection with shafts of centrifugal pumps worn at the stuffing-boxes. Upon one 400-hp.

pump where the shaft became badly worn, it was built up with stainless steel and machined at a total cost of $35, whereas a new machined shaft would have cost $250. The shaft so reconditioned proved durable, for it was in good condition after 14 months of service.

Further justification of the metal-spraying process was found in its variety of jobs for which it was found suitable, with savings in each. This process, for instance, was used in place of electroplating. A large molded part cost $89.75 to electroplate with zinc and aluminum. Spraying with zinc cost but $22.32. Seventy of these were plated and 70 sprayed at another time, the costs being $6282.50 and $1562.40 respectively, this one job's saving being almost five times the cost of the spraying equipment. Still another instance where savings were effected was in reclaiming parts which cost from $25 to $125, after they had been machined in error below size. Cost of reclamation by spraying was about $2 or $3 per part.

This is an excellent example of the selection of a technical process that brings great savings, greater convenience, and a variety of uses, but justification of which is uncertain without actual cost records on the jobs it is intended to do.

Information from: "Paying Investments in New Equipment," James W. Gibbons, Machinery, *August, 1937, p. 771.*

STUDY 6

REDESIGN OF LINE OF ELECTRICALLY OPERATED PROPELLER FANS

For several years, a manufacturer has built and marketed a line of electrically driven disc or propeller fans for wall mounting in ventilating enclosed structures. Simplicity in construction and operation called for these to be built as a unit, consisting of mounting ring, within which the propeller fan wheel operates, the latter being mounted directly on the motor shaft. The motor, itself, is supported by three arms extending radially from the fan ring to the motor frame. Eight ring sizes were required, ranging from 18 to 38 in., and for each were required different sets of mounting arms.

Motor characteristics had to be selected for each design and speed. Since complete fan units were furnished to operate upon all commercial electrical circuits, and the speed of alternating-current motors is fixed by the frequency of the current, a wide variety of motors had to be made available and carried in stock as well as completely assembled units. Alternating-current fan assemblies of 1750 r.p.m. (4-pole,

60 cycles) were required on the four smaller sizes, and 1140 r.p.m. (6-pole, 60 cycles) for the four larger sizes, as well as 1440 r.p.m. (2-pole, 25 cycles)—all suitable for operation on 110- and 220-volt circuits. Correspondingly, direct-current fans of approximately the same speeds were needed for both 115 volts and 230 volts. Higher speeds were avoided on account of the necessity of quiet operation. Further complications arose because mechanical dimensions of the motors varied according to the type of motor required for the circuit, and it was therefore necessary to provide a large variety of mounting arms and also a variety of fan wheels on account of the various shaft diameters. Ordinarily, then, it was necessary for this manufacturer to carry in stock:

16 ratings of direct-current motors.
16 ratings of alternating-current 60-cycle motors.
16 ratings of alternating-current 25-cycle motors.
8 sizes of fan rings.
36 sizes of mounting arms (some being common to various motor sizes).

Thus, the fan manufacturer was faced with the manufacturing and stocking of a large variety of parts, and carrying in stock a large variety of motors and also assembled fans, in order to provide prompt delivery. Motor purchases were necessarily made in small quantities for any given rating, and therefore relatively high prices applied.

After a careful study of possible improvements in design, it was found that a distinct economic advantage could be gained if the fan frame could be made so as to include the fan bearing, and allow for driving the fan by means of a V-belt. Thus, all fan units of a given diameter could be duplicates, with the exception of the pulley. Motor mounting brackets were designed to attach to the fan frame so as to permit bolting thereto motors of a variety of mechanical dimensions. Furthermore, these mounting brackets could be adjusted to permit tightening the belts. Thus standard motors of a limited number of ratings could be purchased in quantities.

The flexibility of the new design accomplished these principal advantages:

1. Increase in quantity manufacture of a lesser number of parts.
2. Decrease in the variety and volume of stocks carried.
3. Operation of the fan wheel at just the right speed to obtain best results, irrespective of the motor speed.
4. The use of higher-speed motors at a saving in cost. Also the buying of motors in greater quantities with resulting savings over previous

small-lot purchases. Furthermore, standardized stock motors are employed.

5. Simplicity in making motor substitutions in the warehouse or in customers' hands.

The general scheme of how this economic problem in design was solved is shown in the following sketches.

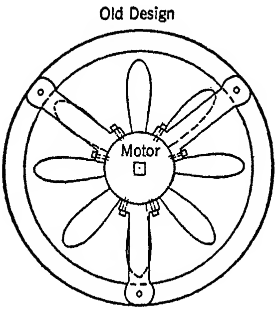

FIGURE 4. The original design.

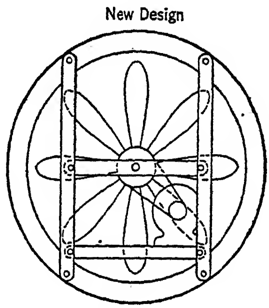

FIGURE 5. The new design.

STUDY 7

JUSTIFICATION OF WELDING APPLICATIONS

There are many manufacturing and construction companies in business today that are turning to electric arc welding or gas welding in their respective manufacturing or construction activities as a matter of economy and improvement of product. Is this justified, and what are the relative advantages of welded construction over riveting or other means of fabrication? What has welding to recommend it in small jobs? In larger fabrication work?

In general, welding may be said to have the following recommendations—for which examples are cited as proof:

1. Welded construction is simple as compared to other methods, and this simplicity permits great savings in both weight and cost of finished product or structure. Much less time is required to do a job by welding.

2. When welding replaces riveted construction, complicated designing and detailing are cut out, handling is reduced, and drilling and punching are entirely eliminated.

3. Often welding is suggested to replace cast construction. This simplifies designs, eliminates patterns, reduces materials cost, saves labor, absorbs fixed charges, minimizes inventory, and permits greater freedom in design. It reduces weight, resulting in lower freight charges, quicker delivery, and less breakage.

4. Quality of finished product is another item that must be considered. This, when welded construction is used, is often equal to or even better than the properties of the steel being welded. This applies to tensile strength, ductility, and resistance to fatigue, impact, and corrosion.

Engineers investigating welding want more definite proof of this superiority of welding over other forms of construction. If these advantages can be upheld in actual practice, then it would seem that welding is economically justified in many respects.

For such proof, the engineers go to the files of a prominent welding machine manufacturer, where the following examples applying to arc welding are found:

Machine Parts

1. Cast *vs.* welding: The weight of a frame for a "dough divider" was cut in half by welded instead of cast construction.

2. Cast *vs.* welding: A stator ring and base made by welding weighs 8400 lb. or half as much as a cast stator. Fabrication costs are but 30 to 40 per cent those of cast.

3. Cast *vs.* welding: A 12-ft-diameter sprocket wheel was specified to be finished within ⅛-in. tolerance. No foundry would guarantee a steel casting to finish in less than 1-in. By arc welding, fabrication was completed successfully to specifications.

4. Other examples of machine parts are:

	Cost Welded	*Cost Old Method*
3-legged stand for vegetable-peeling machine	$12.64	$28.70
Generator bracket	0.85	1.25
Sliding base for motor	1.25	4.00

Machines

1. Riveted *vs.* welding: A crawler shovel whose boom and dipper stick were changed from riveted to welded construction weighs 10 per cent less. The boom is 36 ft. long and the stick is 28 ft. long; the shovel is said to be twice as strong and cost about 20 per cent less than by the riveted design.

2. A California hoist manufacturer saves $250 to $500 respectively on his small and large units by adopting arc-welded construction.

3. Another phase of arc-welding weight-reducing advantages is brought out by a Pennsylvania manufacturer of jaw crushers. He reduces the weight of the frames of his 30 in. by 36 in. type-H jaw crushers some 50 per cent and thereby saves his customers a great deal in freight and handling costs.

Railroad Equipment

1. A Chicago, Milwaukee, St. Paul and Pacific passenger coach weighs but 65 per cent as much when welded as when riveted. This saving in weight is a great advantage in railway operations and is a much-discussed item in railway circles.

Shipbuilding

1. A 300-ft. freight vessel has about 16 per cent greater capacity by welded construction. It carries 300 tons more cargo than a sister ship built by riveting.

2. Another steam vessel had its deadweight so decreased by welding that the owner states he gets a free trip each year or so from the savings effected.

Metal Furniture

1. In the manufacture of the popular metal furniture, a certain plant in Illinois saved $30 per day on one job alone by changing to arc-welded construction.

Steam Piping

1. It has been found that one of the big advantages of electric welding in piping work is the speed with which pipes may be insulated. Insulation of a welded line takes about one-half as long as a coupled line because the absence of a coupling makes it possible to fit standard asbestos covering without cutting around and cementing at the joints. Approximately 20 per cent savings are shown in welded over coupled piping.

Buildings

1. A 200,000 sq. ft. factory building of all welded rigid sawtooth frame design was completed in less than 100 working days for the Lincoln Electric Company of Cleveland. The building contains no roof trusses. Aside from fast construction and unrestricted interior spaces, arc welding showed a 10 per cent saving in fabrication and 10 per cent in erection on this 1314-ton steel frame.

2. A 2-story factory addition was arc welded at a saving of $2800 over riveting. Such savings are due to the simplicity of the welding process. Structural members are joined directly together without intermediate connecting members, thus saving time and materials, simplifying detailing and designing, and reducing handling. The approximate total saving by welding over riveting here is 15 per cent.

And so we see that, from records of previous happenings, engineers sometimes find the answer to their economic problems. From these examples of the savings in cost, weight, and time plus other advantages, it would appear entirely justifiable, in many *similar* cases, to go from cast construction in factories or from riveting, pipe coupling, etc., to electric arc welding. The savings are of sufficient magnitude to justify a change, and often many advantages follow which cannot be evaluated in dollars and cents.

Information courtesy: Lincoln Electric Company, Cleveland, Ohio.

STUDY 8

POWER TRANSMISSION—UNIT DRIVE VS. GROUP DRIVE

One of the most important problems in manufacturing is the transmission and application of power to the individual machine. In a large percentage of manufacturing plants, the losses in power transmission from the source of factory power to the point of use represent more than 25 per cent of the total power consumed.

There are three general ways of driving machinery in a factory:

1. One single power source is used, such as an engine or motor, transmitting the power to each machine by mechanical means.
2. The machines to be driven are divided into groups, and an engine or motor is employed to drive each group by mechanical means.
3. Each machine is driven by a single source of power, usually a motor. Today, with the wide availability of electric power, most machinery manufacturers supply machinery either with the motor and control equipment, or in such a way that it can be easily connected for electric drive. Many machines are now designed so that more than one motor is used, where several operations are included in one machine.

What economical and cost factors, then, should be considered in the selection of the proper method of power transmission? These factors might be grouped thus:

1. Cost of investment in the power-transmission system.
2. Cost of maintenance.
3. Cost of operation.
4. Relations between the system and the costs of production flow.
5. Relations between the system and the costs of materials handling.
6. Relations between the system and the costs of labor.
7. Relations between the system and plant illumination, safety, cleanliness, and comfort of employees.

Other items which must be considered in the selection are:

1. Any need for machine mobility.
2. Whether production is steady or "spotted" with excessive operations at times and sharp curtailment at others.
3. Type of operations done by the plant, and whether additional machines are soon to be added.

Not until the advent of the electric motor did the latter two transmission methods start to develop. At first, motors were used to furnish

power for lineshafts which served a whole shop, but soon the idea of breaking down a shop into groups of machines, each group being a logical one, was evolved. This was the modern "group drive." Then, as smaller motors and control were further perfected, the "unit drive" in which each machine was driven by a motor came into being. Because of the many apparent advantages of this idea, it spread rapidly, sometimes being employed out of proportion to economic justification. On the other hand, the group drive was a compromise between the lineshaft and unit drive with power delivered by lineshaft to a logical grouping of machines. Often such a compromise is desirable, economically, despite unit drive advantages.

From what has been developed, then, it would appear the problem at hand is whether modern group drive or unit drive should be used in a plant. The old lineshaft method is so costly, disadvantageous, and outmoded that it does not enter into the economics of the problem at all, for it is not even considered in the selection.

Let us, then, examine the actual figures in a particular case of the economics of modern group drive *vs.* unit drive, and from these determine which is the more economical means of power transmission. We select, for this study, a department of a metal-working shop. Forty-two heavy-duty buffers are now individually driven (unit drive) by motors of 20 hp. connected to each machine by short belts. The motors have two bearings per drive and are mounted directly on the machine frames.

It is proposed that it would be economical to divide these 42 machines into 8 logical groups—utilizing normal load factors and hence securing high motor efficiency. For each group would be one 30-hp. motor belt-connected to overhead shaft, and machines are to receive power by belt likewise, from the group lineshaft. Shafts are 30 ft. long, 2$\frac{3}{16}$ in. in diameter, with 9 anti-friction bearings per drive.

In the following survey are the costs by each method, so that we may actually determine which is economically the better:

UNIT DRIVE

42 heavy-duty buffers, unit drive, utilizing 20-hp. motors:

1. Total installed hp.	840	(As installed, 42 motors × 20 hp.)
2. Operating hours per year. .	4368	(As obtained from management of shop)
3. Average motor load.	25%	(Computed, kw. input × motor efficiency)
4. Average motor efficiency. . .	78%	(Obtained from motor-efficiency curves)
5. Average drive efficiency. . .	73%	(Allowing 5% mechanical losses)
6. Average power factor.	0.55	(Obtained from power-factor curves)

Installation costs:

Motors and controls......	$9,198	(From motor price book)
Wiring.................	7,721	(From table of average wiring cost)
Mechanical drives........	1,932	(Compiled from equipment catalogues)
Total...............	$18,851	
Fixed charges @ 15%....	2,827 per year.	

Power computation:

840 hp. × 25% average motor load = 210 hp. output of system.
210 hp. output ÷ 78% average motor efficiency = 269 hp. input to system.
269 hp. × .746 (kw. per hp.) = 200 kw.
200 kw. × 4368 hr. operation per year = 873,600 kwhr. per year.

873,600 × 0.01 per kwhr. (cost to management of shop)...	=	$8,736.00 per yr.
Power-factor penalty (or fixed charges on power-factor corrective equipment due to operation below 85% power factor).................................	=	450.00 per yr.
Total annual power cost..............................		$9,186.00

Operating Cost Computation:

Fixed charges..........................	$2,827.00
Power charges..........................	9,186.00
Maintenance charges:	
42 motors	
42 controls	
42 drives	
84 bearings	
(On basis of $10 per drive)..............	420.00
Annual cost......................	$12,433.00

MODERN GROUP DRIVE

Same 42 buffers, divided into 8 groups, each group driven by one 30-hp. motor by means of group overhead shafting:

1. Total installed hp.........	240	(Unit motor drive hp. × average motor load)
2. Operating hours per year..	4368	(As before)
3. Average motor load.......	88%	(From efficiency curves and normal load factor)
4. Average motor efficiency...	91%	(From motor efficiency curves)
5. Average drive efficiency...	86%	(Allowing 5% for mechanical losses)
6. Average power factor.....	0.90	(From power-factor curves)

Installation costs:

Motors and controls..	$2,394
Wiring..	1,707
Drives..	3,800
Total..	$7,901
Fixed charges @ 15%...	1,185 per yr.

Power computation:

873,600 kwhr. × 73% (average unit drive efficiency) = 637,728 kwhr. actually consumed by machines operating for one year.

637,728 kwhr. ÷ 86% (average modern group drive efficiency) = 741,500 kwhr. required by modern group drive system.

741,500 kwhr. × 0.01..	= $7,415 per yr.
Power-factor charges—none..	0
Total annual power cost..	$7,415

Operating cost computation:

Fixed charges	$1,185.00
Power charges	7,415.00
Maintenance charges:	
8 motors	
8 controls	
50 drives	
90 bearings	
(On basis of $5.00 per drive)	250.00
Annual cost	$8,850.00

COMPARISON OF RESULTS

Annual cost of unit drive system	$12,433.00
Annual cost of modern group drive system	8,850.00
Saving effected by modern group drive	$ 3,583.00

From the results of these calculations which obviously do not include intangible factors, we see that, economically, the selection of a power drive should, in this particular case, be modern group drive rather than unit drive. In other instances a different result might be obtained.

One disadvantage of the unit drive is the necessity of "overmotoring" or having available a total horsepower equal to the sum of all starting loads or maximum operating loads. In group drives, one motor, whose horsepower is but the sum of all normal running loads, is used. Hence, load factors may be higher and less installed horsepower required than with unit drive. It is a known fact that one motor of sufficient horsepower to drive a group system will cost less than the many motors in an equivalent unit drive set-up. Motor costs per horsepower rise rapidly as the motor horsepower comes down. This fact of overmotoring plus extra expense of additional wiring and control ordinarily will exceed any increased cost of group-drive mechanical equipment.

Unit drive, on the other hand, provides for each machine an independent source of power, and permits any machine to be operated while others are idle. Motor-driven machines may be added without making any change in the power transmission system. A factory becomes safer and cleaner, and the obstruction of light is eliminated, where individual drive is used. For some types of machine and work, a wide range of exact speeds is obtained more easily by the use of certain types of motors than by mechanical devices.

Each set of factory conditions presents an interesting problem for the engineer, and an evaluation of the advantages of group drive *vs.*

individual drive requires a consideration of intangible factors, as well as those which can be definitely established on a dollar and cents basis.

The example of the calculations upon unit drive and modern group drive and some other data from "The Economics of Industrial Power Transmission," Francis Juraschek, Iron Age, *November 19, 1936, p. 36.*

STUDY 9

SELECTION OF THE TYPE OF COAL FOR AN INDUSTRIAL PLANT

The problem of the selection of the type of coal for an industrial plant has many economic aspects. Let us consider the possibility of pulverizing and burning some of the estimated 10 millions of tons of anthracite wastes (culm, silt, slush, river coal) that are dumped each year as worthless.

Because of the higher prices of smaller sizes of anthracite plus cost of pulverizing, this fuel has been little used industrially in pulverized form. But could not these anthracite wastes be pulverized and used at a cost comparable to or less than that for other forms of pulverized coal? Upon investigation, it was found that this idea actually could be carried out—often at a saving in fuel costs.

Four fuels were studied in an effort to determine when it would be economical to fire pulverized anthracite wastes. The fuels studied were:

1. Stoker anthracite (sized—consisting of 75 per cent No. 3 and 25 per cent No. 4 buckwheat).
2. Pittsburgh bituminous—pulverized, high volatile.
3. Pocahontas bituminous—pulverized, low volatile.
4. Anthracite silt or culm—pulverized (which we are attempting to justify economically).

The study of these fuels was on the basis of a 100,000 lb./hr. boiler unit at 60 per cent load factor. Taking into consideration all costs—operating costs of power, maintenance and labor, and fixed charges on firing apparatus—values were found for how much the other fuels should cost per ton if, for a selected price for anthracite wastes, all four fuels were to be equally as economical to use. These results we see in the curves shown in Fig. 6.

By reading the cost of anthracite silt per ton on the bottom scale, then going up to intersect any one of the other three fuel curves, and thence going horizontally to the vertical scale, we obtain the amount

which any of the other fuels may cost per ton at which the firing costs will be equal to those of the anthracite silt at the selected price. To illustrate, if we can buy anthracite wastes for \$3 per ton, the cost of firing pulverized silt or wastes will equal the cost of firing stoker anthracite when it is purchased at \$3.25 per ton or Pittsburgh bituminous

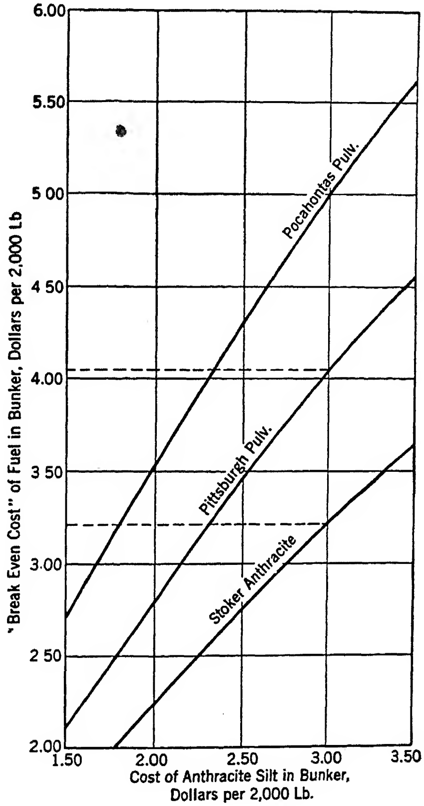

FIGURE 6. Comparative fuel costs for equal economy (100,000 lb. per hr. boiler unit).

at \$4.05 per ton or Pocahontas at \$5.00 per ton. Hence, buying anthracite silt at any cost *less than \$3.00 per ton* will effect savings over stoker anthracite, Pittsburgh bituminous or Pocahontas at \$3.25, \$4.05, or \$5.00 per ton respectively.

Further investigation of a plant in the East which uses 100 tons or more of fuel per day showed yearly savings by using anthracite silt or culm as follows:

Fuel	Cost at Plant per Ton	Cost of Firing per Year	Saving per Year by Using Anthracite Culm
1. Stoker anthracite......	$3.50–3.80	$122,000–131,000	$11,000–24,000
2. Pittsburgh bituminous.	4.70–5.00	131,000–138,000	20,000–31,000
3. Pocahontas...........	5.10–5.50	113,000–120,000	2,000–13,000
4. Culm or silt..........	2.85–3.00	107,000–111,000	

With costs of each fuel as given for this one instance, it is seen how it would be entirely justifiable to install pulverizing equipment for anthracite wastes, since the savings effected would shortly pay off the investment cost of such equipment.

An advantage of low-grade pulverized anthracite is that it may be as easily directly fired now as bituminous coal. Anthracite pulverizing and combustion require no extra operating skill or special treatment in spite of its low volatility (2½ to 10 per cent), high moisture content (10-20 per cent), and low grindability (less than 40 per cent, usually).

On the other hand, to get good combustion, pulverization must be very fine, and this means larger pulverizers which cost more and have higher operating costs than for bituminous coal. These increased first and operating costs are ordinarily balanced out, however, by the lower price per ton of the fuel. Separating burners are necessary to concentrate the fuel mixture and maintain proper ratio of air to coal.

Despite these added costs in some respects, in one instance $80 to $100 per day was saved with pulverized anthracite over pulverized bituminous burners, in side-by-side comparison. We find anthracite fines being pulverized and burnt successfully with no pre-drying; automatic firing apparatus takes care of load swings rapidly, and steam-pressure fluctuations are small. Ignition with the fuel is self-sustaining; carbon in refuse and unburned carbon losses are small; and the appearance of the stack is ordinarily good.

We can conclude, then, that in many cases, anthracite fines when pulverized can be competitive with other better fuels, especially in areas near anthracite regions where freight rates will not be prohibitive. In fact, savings sometimes are so great as to pay off the initial cost of the equipment for pulverizing the anthracite culm within one year.

Example and curve, from: "The Pulverization of Anthracite for Commercial Use," Martin Frisch, Transactions *of the First Annual Anthracite Conference of Lehigh University, April 29-30, 1938, Paper XII.*

STUDY 10

MECHANICAL LOADING IN COAL MINING

The problem in coal mining of when and where to use mechanical loading is a difficult one requiring careful balancing of all effects of physical mining against all operating functions and efficiencies of installed equipment. Prejudice must be thrown aside and both beneficial and detrimental factors thoroughly studied in each individual case. What, then, are some of these factors which the mining engineer studies when debating mechanical loading and other mining mechanization?

All important are the physical characteristics of the coal seam, for these determine size, capacity, and type of equipment needed. For instance:

1. Ventilating and safety cost of mechanical loading may vary with classification of the mine as gaseous or non-gaseous.
2. Cost increases may be due to need for increased ventilating due to greater velocities and volumes of air in working places. Cost may also rise because of necessary face sprinkling to increase visability and rock dusting to diminish hazards.
3. The thickness of coal (minimum, average, and maximum) and pitch of seam must be considered if correct size of equipment is to be chosen. This is important, for equipment must be of such dimensions as to have sufficient power to handle all loads quickly and give sufficient clearances under all working conditions.
4. Kind and texture of the coal must be observed, for these are determining factors as regards drilling, power, and necessary explosives, and also influence the way in which the prepared faces will "load out" mechanically. Choice of type of mechanical loader, power, and capacity is largely determined by the size and shape of blocks of coal produced and by the percentage of coarse or fine coal desired for a given market.
5. Depth of cover overlying the coal and the nature of the "roof" affect mechanical loading from the concentration standpoint of panel dimensions; width and length of entries; spacing, width, and depth of rooms and pillars; or use of longface or longwall mining.

The type of floor in a given mine requires study in deciding upon economic justification of mechanical loading:

1. Hard floors increase the cost of holding temporary rails in place for track-mounted loaders. They also reduce the pitch on which a caterpillar type of machine can maneuver.
2. Soft fireclay often absorbs enough moisture so that it bogs down machine and track. It may also scale off and become mixed with the coal during loading.

Speed of coal gathering at different points of attack is an important cost item and requires study of a proposed loader in relation to advancing or retreating pillaring and longface methods. Naturally, anything indicative of slow loading is predictive of high operating costs.

Of wide importance is the relationship of the operating cycle of various units to one another. For instance, considering mechanical loading from the economic standpoint requires a study of available power, its kind, its volume, and the efficiency of its distribution. If a loader is designed for 250-volt operation but is put on a line at 200 volts, operation is possible but efficiency falls greatly and high electrical maintenance costs result. When loading is changed from hand to 100 per cent mechanical, the mining engineer can expect his power load to rise at least 1 kwhr. per ton of production. He may find this an economic disadvantage of mechanical loading.

Involved with the problem of hand *vs.* mechanical loading and selection of proper equipment is the item of "unbalancing" of loading and cutter units. If the capacity of the cutter is below the average loader production per shift, it is necessary to pay overtime wages to keep the prepared coal ahead of the loader. On the other hand, cost of operation rises as the result of mechanization when a high-speed cutter is put into a territory where the loader average is less than the cutter capacity.

Transportation is important in relation to loading methods. Efficiency of dispatching loads and distributing empty cars may determine the economy of mechanical loading *vs.* hand loading. The number of pit cars that are available relative to length of haul, and the round trips per shift that are possible, enter into the problem. Conveyor transportation may also be a factor.

A final set of variables which affect mechanical loader savings are concerned with the direct labor cost per ton of production. Labor is about 60 per cent of all f.o.b. mine costs, and hence, to get an accurate picture of hand loading *vs.* mechanical loading, a complete analysis of all operating phases must be made.[1]

Such are a few of the many things which must be investigated by the mining engineer when he attempts to justify economically hand or mechanical loading in a coal mine. Each factor may point to rising or decreasing cost items which may be determinant in the final decision. They should be carefully studied from every angle. The variables which contribute toward such a decision are by no means only those

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[1] An interesting tabulation and calculation of all costs in hand *vs.* mechanical loading is found in *Coal Age*, October, 1937, p. 62.

discussed here, but these variables have been completely classified in the following way:

VARIABLES IN MINING MECHANIZATION [2]

1. Attitude of men and management.
2. Operating organization efficiency.
3. Kind of mine—shaft, slope, or drift.
4. Thickness of seam—minimum, maximum.
5. Character and texture of coal.
6. Pitch of seam.
7. Wet or dry operation.
8. Character of floor.
9. Character of roof.
10. Seam impurities—banded, inherent.
11. Depth of cover.
12. System of mining.
13. Panel dimensions.
14. Width of entries.
15. Width of rooms.
16. Longface or longwall.
17. Timbering systems.
18. Pillar extraction—advancing, retreating.
19. Surface cleaning facilities.
20. Power and distribution system—voltage.
21. Hoisting and transportation.
22. Motive power—condition and capacity.
23. Rail weights, gage and condition of track.
24. Conveyors—condition and capacity
25. Average length of main haulage.
26. Average tonnage hauled per trip.
27. Type and capacity of cars.
28. Number and condition of cars on hand.
29. Dispatching system and efficiency.
30. Cutting methods and costs.
31. Drilling methods and costs.
32. Blasting methods and costs.
33. Loading methods and costs.
34. Yardage and deadwork costs.
35. Contract and day wage rates.

Information from: "Analyzing Variables—Which Can Make or Break Program of Underground Mechanization," Walter M. Dake, Coal Age, *October, 1937, p. 59.*

[2] Reproduced from *Coal Age,* October, 1937, p. 61.

Item	*Investment* Steam	Diesel-Electric
1. Investment in motive power	$ 8,975	$64,000
2. Investment in combine	8,513	......
3. Investment in coach	10,904	12,000
4. *Total*	$28,392	$76,000

Item	*Operating Costs per Train-Mile* Steam	Diesel-Electric
5. Wages—1 engineer	$0.2550	$0.2550
6. Wages—1 fireman	.1900	.....
7. Wages—1 conductor	.2170	.2170
8. Wages—1 baggageman	.1570	.1570
9. *Total wages entire train crew*	.8190	.6290
10. Motive power repairs	.2430	.0440
11. Car repairs	.0376	.0376
12. Fuel	.1036	.0250
13. Lubrication	.0067	.0085
14. Water	.0253	.....
15. Enginehouse expense	.1012	.0150
16. Miscellaneous supplies	.0079	.0079
17. *Total*	.5253	.1380
Interest and Depreciation per Train-Mile		
18. Interest	.0574	.1540
19. Motive power depreciation	.0076	.0648
20. Trailer depreciation	.0164	.0101
21. *Total interest and depreciation*	.0814	
22. *Grand total* (Items 9, 17, 21)	1.4257	

We can now calculate yearly operating costs as follows:

Steam operation = 29,640 miles × 1.4257 = ...	$42,300
Diesel-electric operation = 29,640 × .9959 = ...	29,500
Savings of Diesel over steam per year	$12,800

If desired, it is possible to eliminate the baggageman on such a Diesel-electric run, in which case his wages of approximately $4600 per year (29,640 × 0.1570) would bring the annual savings of Diesel-electric operation over steam to approximately $17,400.

From this complete breakdown and analysis of the two methods of operation, it has been found that the savings effected by Diesel-electric service are great enough to justify economically the change from steam to Diesel-electric motive power. Even though a baggageman is employed on the Diesel-electric run, the $12,800 yearly savings, when put on 5 per cent compound annual interest, will retire the Diesel mo-

tor car investment in 5 years and 7 months. If the baggageman should be eliminated, the increase in savings to $17,400 annually will retire the investment in 3 years and 6 months.

This is an excellent example of how closely such economic selection problems are studied and calculated in rail transportation. Few other industries keep as complete and accurate operating figures as the railroads from which to carry on economic analyses such as this.

From study made by: The Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania.

STUDY 14

SELECTION OF URBAN TRANSPORTATION METHODS

A problem facing almost every city today is to provide economically for the transportation of large numbers of its people to and from shopping centers, work, recreation spots, schools, etc. In this economic study, we shall investigate the various facilities for mass transportation which ordinarily operate under franchises from the city authorities.

First, what is required to transport city dwellers? We can immediately eliminate the idea of doing this entire job by taxi or private motor car, for our cities would have to be completely rebuilt if they were to accommodate highways adequate to this purpose. We must have some form of "mass" transportation. The ideal system should transport the public:

1. With the minimum of waiting time.
2. With reasonable comfort.
3. At the greatest speed compatible with safety.
4. With least interference with other traffic.
5. At the lowest possible price, including fixed charges on all capital invested.

Today, we find four main classes of mass transportation from which to select. They are:

1. Surface street railways.
2. Trolley coach lines.
3. Gas bus lines.
4. Rapid transit lines—elevated or subways.

Scores of economic factors enter into the selection of the proper mode of city transportation. Beginning in locations where routes are limited to 100 to 200 passengers per hour (in direction of the maximum

movement) such as small cities, the traffic can be handled nicely by rather small vehicles which operate on headways of 15 to 20 minutes. This indicates the adoption of *gas buses* because of their low operating costs and very low initial investment. Smaller, cheaper buses (seating, say, 20 passengers and carrying 10 standing) operated every 15 minutes can nicely accommodate 120 passengers per hour, at an investment cost of but \$3000 to \$4000 per route mile including garage facilities. This equipment is especially desirable in pioneering in new territory in smaller to medium-sized cities. Bigger machines (30 passengers) on 15-minute service can facilitate the handling of some 180 passengers per hour at an investment cost of about \$8000 to \$9000 per route mile. Forty passenger buses, on 15-minute service, carry 240 passengers per hour at an investment of \$12,000 per route mile. But, as we come to traffic of this density, we must watch economy closely.

Near this density point, we find the trolley coach coming into economic justification. Externally, except for a trolley, these resemble gas buses. Trolley coaches operate by electric motors and control, deriving power from a pair of trolley wires through poles long enough so that the buses can pull out from the trolley wires some 12 to 14 feet on either side—hence allowing for passing cars, pulling into the curb, and other flexibilities of the gas bus, combined with the advantages of electrical operation.

The investment for the trolley coach is great as compared to the gas bus. A 4-wire pole line usually may come from \$5000 to \$10,000 per route mile to construct. Substations providing from 30 to 40 kw. per vehicle are required at \$1500 to \$2000. Thirty-passenger trolley coaches on 15-minute service will cost in investment about \$6000 per route mile more than similar gas bus service. Forty-passenger, 5-minute trolley coach service will cost some \$12,000 per route mile more than gas bus. In the electric coach's favor, though, is its low depreciation rate due to its long economic life. Substations and lines, likewise, have low depreciation rates—about, or less than, 4 and 5 per cent, respectively. As a whole, however, the gas bus emerges with about \$400 to \$700 per route mile less annual charges (fixed) for depreciation and interest than the trolley coach, but this is only 0.6 to 0.8 cent per vehicle mile.

But there are other factors in favor of the trolley coach, for records of various companies show that often, in heavy service, the savings in maintenance of equipment, garage, and power over the gas bus more than equal the higher fixed charges of the trolley coach. That must be combined with the fact that trolley coaches attract additional traffic

because of their smoother, quieter, more comfortable and faster rides. Summarizing this comparison of gas bus and trolley coach, then, it is safe to say that trolley coaches offer a lower cost of service (including investment charges) when traffic density is such as to support 30-passenger (or more) vehicles on 15-minute (or less) service. Since this is true on "new" routes, it is very much more so where trolley coaches are replacing street railway cars because of the distribution and substation equipment already paid for and installed.

Consider now a condition of very heavy traffic. Using standard-type 40-passenger gas buses, carrying as many as 70 passengers in rush periods with fair comfort, and operating on the very minimum headway of 40 seconds or 90 units per hour, 6300 people might be carried per hour in the direction of maximum traffic. Trolley coaches of the same capacity are built larger and with wider aisles so they can carry loads 20 to 25 per cent greater during rush than gas buses, or from 7600 to 7800 passengers per hour. In this situation, we have an investment requirement of perhaps $245,000 per route mile for the gas buses, and $275,000 for the trolley coaches. Plainly, it is now economically justifiable to adopt still another method of transportation—the street car. Modern cars (such as the new PCC cars) [1] seat 60 and handle 120 rush-hour passengers, so that only 53 cars can handle the 6300 passengers of the 90 gas buses or 65 street cars can handle the 7800 previously carried by 90 trolley coaches.

The street-car system, if put down on paved streets, may run as high as $100,000 per route mile for track alone. Investment in vehicles as well as costs of substations, lines, and shop facilities will be less for the railway. However, including track, total investment costs will very likely run about $320,000 per route mile, which is 15 per cent more than that of the trolley coach line and 30 per cent above gas buses. We must not forget, though, that there are differences in depreciation rates—so much so that it will be found that the fixed charges of rail, trolley coach, and gas bus systems of this magnitude will all be approximately equal. Another factor in favor of the rail system is operating costs. True enough, operating costs "per car" far exceed the "per vehicle" costs of the other two systems; but, because of the greatly reduced number of vehicles in the rail system to handle a volume of

[1] The PCC car is a modern version of the street car, the development of which was initiated and sponsored by executives of leading street-railway companies. These executives formed the Electric Railway Presidents' Conference Committee as an instrumentality through which a modernized car might be developed. (See "The PCC Street Car," C. F. Hirshfeld, *Electrical Engineering,* February, 1938, p. 61.)

traffic such as indicated here, the "total operating costs" of the rail system are least of all. Considering all these factors—investment, maintenance, operation costs, etc.—the cost of rail service by modern street cars in heavy traffic as assumed in this discussion will be about $35,000 and $22,000 less per route mile per year than that of the gas bus and trolley coach line, respectively. And accompanying this economic conclusion is the reduced street congestion which results when the street car is adopted. Summarizing, then, we may say that the advantages of the large-capacity street or rail car become less apparent as traffic density decreases. In fact, to handle the rush hours that require 3-minute service by rail or 2-minute service by electric trolley coach, the costs of service are equal by the two systems.

The fourth and last method of mass transportation to be considered in this problem of selecting the mode of service is the rapid transit system. These systems do not operate on public streets but over private rights of way, usually elevated above street level or underground. Such systems cost enormously, but their carrying capacities are just as enormously increased. For instance, the new four-track New York municipal subway has a probable one-way capacity, by using all tracks, of more than 180,000 passengers per hour.

Investments in these systems, which, of course, are justified only by tremendous traffic, are so large and varied that any figure is but an average. Perhaps $12,000,000 per route mile is as close as it is possible to make such a figure. But this is not so alarming an amount if one considers the benefits that come in expediting passenger traffic. No other form of expenditure of this magnitude or greater can be devised that will permit the number of people carried by subway to be carried successfully by other forms of transportation in the city. Nor can the subway speed be equaled.

Subways cost fully twice per route mile as much as the most modern surface street railway of equal hourly movement. But even with this fact, high fixed charges still do not reflect upon subway users. This is seen if we consider that only about 25 per cent of total subway costs go for equipment (cars, distribution, signals, shops, etc.), while 75 per cent goes into non-depreciable items such as construction and real estate. Moreover, track and car depreciation rates on the subway are lower than for the surface system. Riders of the subway go four times as far as the surface line's riders, as a rule. If this were not so, and riders rode the street systems as they do the subways, revenues per car or bus mile would never cover operating expenses. Subways operate at about 50 to 60 per cent of their revenues. A distinct advantage

to the subway or rapid transit operator is his lower operating costs per car mile and per passenger as compared to surface lines.

This study has endeavored to show what factors are considered and where the various economic limitations of each method of mass transportation are placed. It can readily be summarized, though, that the selection of the most economical transportation system for a city depends upon traffic density during rush hours to and from business districts of the city. Of the four systems, the gas bus, trolley coach, and street car may more or less be debated upon since their differences are not too great, but the fourth system of rapid transit lines is set apart as in a separate class since this type of service cannot be touched by other forms of transportation. Certainly, the rapid transit is a valuable asset to any large city that can maintain it.

Eliminating rapid transit operation, then, the modern street railway undoubtedly is the best for heavy traffic service, but, as traffic density decreases, the trolley coach becomes outstandingly advantageous. Rail systems in cities even up to 500,000 population often are not economically justified. Electric operation seems the most advantageous for most service not only from an economic outlook but also because of more comfortable, safer, cleaner, and faster service. The one item of eliminating fumes and gases in the air recommends electric operation highly.

Information from: "Application of Modern Electric Vehicles to Urban Transportation," C. M. Davis, Electrical Engineering, *January, 1938, p. 57.*

STUDY 15

REPLACEMENT OF OBSOLETE RAILROAD-SHOP EQUIPMENT

In the present day of financial stress among the railroads of our country, many remedies are suggested, and methods of reducing operating expenses are being explored. Long deferred by a majority of the roads, however, is a modernization of those "necessary evils" which each must maintain—repair shops. It is now acknowledged that 70 per cent of the machinery and equipment in railroad shops is obsolete, and its replacement presents a real economic problem.

One of the first arguments one receives when he broaches this subject to many railroad executives is that modern machines pay when they can be kept busy, but the railroad shop is not on a continuous basis of production. A job may have to be done very quickly, but it may also be the only one of its kind during the day, and the equipment to do that job may lie idle until the next locomotive or car comes in for

rush service. But is it a true contention that modern machines pay only when their load factors are high? A more reasonable answer to whether an obsolete machine still in use should or should not be replaced is whether there is a material saving in the relative cost of doing a piece of work. If the saving can be made, costs are reduced and cheaper and better service can be rendered by the railroad, which should create more business requiring a greater use of the machine, and hence a greater amount of saving through its use. Is it not sound that one contributing cause of the plight of some railroads is the fact that shop equipment has been allowed to become largely obsolete?

In the calculations which follow, it is shown what it is costing the railroad industry when it keeps on using obsolete equipment in one specific instance. From such an example, conclusions can be drawn on the total bill paid annually for obsolescence by the railroad industry.

The calculations below are based upon a new turret lathe which a superintendent of a certain road has ordered. The machine is to be used only for the rough machining of steam chest bushings some 15½ in. in outside diameter. Material of the bushings is gun iron, and, with existing equipment, the machining time is 180 minutes per piece, while records of other users of the new lathe estimate that the job can be done in 40 minutes for each piece. Labor cost is assumed to be 60¢ per hour and overhead 90¢ per hour, or a total of 2½¢ per minute. First we solve this by the Warner and Swasey method, which is most simple:

Cost per piece on old equipment = 180 × 2½ =	$4.50
Estimated cost per piece with new machine = 40 × 2½ =	$1.00
Gross saving per piece by new machine	$3.50

Assuming a 48-minute hour and an 8-hour day, 9½ pieces can be turned out daily with new equipment. Twelve minutes of each hour are allowed for emergencies, operator being away from machine, etc. We shall further assume the average working days per year to be 280.

Gross savings per year = 9½ × 280 × $3.50 =	$9310.00
Cost of turret lathe complete	7324.50
Cost of special tooling	300.00
Total investment	$7624.50
Depreciation on the investment:	
20% on machine and standard equipment	$1464.90
100% on special tooling	300.00
Total depreciation	$1764.90
Net savings per year = $9310.00 − $1764.90 =	$7545.10

If the saving effected by the use of the simple Warner and Swasey method is felt a bit optimistic, we can check it by the replacement formula of the SKF organization, which is interesting since, in the SKF company, a superintendent need only show, by this formula, that equipment he wants will pay for itself within a given period (usually two years), and his requisition is approved. The formula is:

$$M = \frac{C_E + C_T + C_{IX} + C_{DX} + V_B}{(.}$$

in which M = number of months in which equipment will pay for itself

C_E = cost of new equipment to be installed.

C_T = cost of tooling the new equipment.

C_{IX} = the cost of interest for X years at 6 per cent, X equaling the number of years determined upon as the maximum time during which the equipment must pay for itself.

C_{DX} = the cost of depreciation for X years at 10 per cent, X being the same as above.

V_B = book value of the displaced equipment.

R_P = present rate or cost per piece by old machine.

R_E = estimated rate or cost per piece on new equipment.

N_D = number of pieces to be produced per day on the proposed equipment.

D_M = number of working days per month.

S_{OHM} = savings in overhead per month.

Again, we assume that the new lathe is to be written off in five years and that the old machine has a book value of \$500. Then:

$$
\begin{aligned}
C_E &= \$7{,}324.50 \\
C_T &= \$300.00 \\
C_{IX} &= \$2{,}197.35 = (\$7{,}324.50 \times 0.06 \times 5) \\
C_{DX} &= \$3{,}662.25 = (\$7{,}324.50 \times 0.10 \times 5) \\
V_B &= \$500.00 \\
R_P &= \$4.50 \\
R_E &= \$1.00 \\
N_D &= 9.5 \\
D_M &= 24 \\
S_{OHM} &= 0 \text{ (included in calculation of rate per piece).}
\end{aligned}
$$

Hence:

$$M = \frac{\$7{,}324.50 + \$300 + \$2{,}197.35 + \$3{,}662.25 + \$500}{(\$4.50 - \$1.00) \times 9.5 \times 24 + 0}$$

$$M = \frac{\$13{,}984.10}{798} =$$

If the new lathe pays for itself in 17½ months, it must have saved \$7,624.50 over that period. We assumed that the investment is to be written off in five years. In a single month the saving will be

$\frac{\$7{,}624.50}{17.5}$ or \$436; while for the whole five-year period the saving will be $\$436 \times 5 \times 12 = \$26{,}160$. This is \$5,232 per year as compared to \$7,545 as calculated by the simpler method, but still an admirable saving is shown by installing the new lathe.

We can turn to still another more complex formula[1] to check our results again. The formula:

$$V = [(S + T_a + U - E)X + T_b] - \left[Y + K\left(A + \frac{1}{h}\right)\right]$$

where $Y = I\left(A + B + C + \frac{1}{h}\right)$.

in which case, the symbols stand for the following:

A = interest rate, or yearly allowance on investment = 0.06.
B = yearly percentage allowance for insurance, taxes, etc. = 0.01.
C = yearly percentage allowance for upkeep = 0.05.
E = yearly cost of power, supplies, etc., in dollars = 0.
h = expected number of years of life of equipment = 5.
I = initial cost of new equipment in dollars = \$7,624.50.
K = unamortized value of equipment displaced, less its scrap value, in dollars = \$500.
X = percentage of year during which equipment will be in use = 0.93.
S = yearly saving in direct labor cost in dollars
T_a = yearly saving in labor burden in dollars
} $S + T_a = \$9{,}310$.
T_b = yearly fixed charges on old equipment = \$600.
U = yearly saving or earning through increased production in dollars = 0.
Y = yearly cost to maintain new equipment ready for operation in dollars (fixed charges).
V = yearly net operating profit from new equipment, in excess of fixed charges, in dollars.

$$Y = I\left(A + B + C + \frac{1}{h}\right) = \$7624.50\,(0.06 + 0.01 + 0.05 + \tfrac{1}{5})$$

$$= \$7624.50 \times 0.32 = \$2440$$

$$V = [(S + T_a + U - E)X + T_b] - \left[Y + K\left(A + \frac{1}{h}\right)\right]$$

$$= [(9310 + 0 - 0)0.93 + \$600] - [\$2440 + \$500(0.06 + 0.20)]$$
$$= \$6688$$

Example from: "What It Costs to Keep Obsolete Equipment in a Railroad Repair Shop," American Machinist, *May 16, 1929, p. 764.*

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[1] Developed by a committee of the American Society of Mechanical Engineers.

STUDY 16

BORING VS. GRINDING LOCOMOTIVE AIR-PUMP CYLINDERS

The greatest single item of railroad maintenance expense is locomotive repairs, and an important phase of this work is the reconditioning of locomotive air pumps. In order to reduce the cost of this pump reconditioning, it has been suggested that pump cylinders be reconditioned by grinding instead of boring, using an internal grinder especially adapted for the work and equipped with a swiveling type of pump fixture to facilitate adjustments and minimize setting-up time.

After careful study, it was found that by grinding the cylinders, instead of boring, savings could be effected in four distinct ways:

1. Savings in labor costs.
2. Savings in material costs.
3. Savings in maintenance costs.
4. Savings in steam consumption, or operating costs—this being the most important of all savings.

In the selection of methods of maintenance, as in this problem, there are many economic angles from which the methods must be studied and analyzed. For instance, the large savings in labor by changing from boring to grinding are mostly due to the fact that pump cylinders may remain assembled to the center casting when ground. If they are to be bored, the cylinders must be unbolted from the center casting and each cylinder or pair of cylinders set up and machined, and then reassembled. Such boring operation (on an 8½-in. cross-compound pump) requires 10 hours shop labor, and jeopardizes cylinder alignment owing to warping of center castings and difficulty in drawing gaskets down evenly in assembly. Grinding does not disturb the gaskets, it requires 4 instead of 10 hours, and the accuracy of the grinder's swivel feature insures that steam and air cylinders are ground in alignment, resulting in free piston action, straight-line travel of the piston rods through the stuffing-boxes, and minimum, equally distributed wear. Actual savings in labor are about $4.33 per ground pump.

Another advantage in favor of grinding over boring is in the cost of new cylinder castings. Naturally, the number of times a cylinder can be reconditioned by boring or grinding before reaching the ¼-in. oversize limit depends upon *wear* and the *amount of metal removed at each reconditioning.* Boring normally enlarges a cylinder $1/16$-in. and is required every 100,000 miles (about two years of service). Grinding causes but a $1/32$-in. enlargement and usually will last 150,000 miles or three years. Because of the superiority of finish in the ground cyl-

inder and the greater alignment accuracy, the wear is less. From this increase in cylinder life by grinding instead of boring, the outlay for new castings is cut about $7.27 per year per pump.

Still another saving tending to make us decide to adopt grinding instead of boring is that reconditioning is required only every three years instead of two, and hence a unit saving of $2.21 for enlarging piston-heads to fit the enlarged cylinders is made. Another saving is in piston rings. When all these maintenance costs are added to labor and cylinder material costs, we find the annual cost of a ground pump to be but $22 *vs.* $48 for a bored pump. This would certainly justify a change to grinding.

Three distinct technical tests were made to determine the savings in steam consumption due to the superiority of ground cylinders, and from these tests, with a conservative estimate of 50,000 service miles per year per locomotive, an annual saving of $111 per pump was shown. This great saving is due to higher efficiency of ground cylinders and the reduction of steam consumption that results.

From these savings, it is seen that the grinding method saves $48 − $22 + $111, or $137 per year. The machine can grind 600 of the 8½-in. pumps per year, so that, in a shop large enough to provide full-time work for the machine, one grinder, purchased for $6180, would save $137 × 600, or $82,200 per year, or more than 13 times its cost.

Such a machine is equally adaptable to even very small shops, for, when provided with auxiliary equipment, it can be used for other locomotive repair grinding jobs, such as grinding valve motion parts, rod bushings, and driving boxes of the floating bushing type. When it is so used, yearly savings of about $274 per locomotive are possible, and in a shop overhauling only 36 engines per year, this means a saving of about $9860 per year, or over $450 more than the cost of the grinder and its auxiliary equipment. With all these savings definitely known, it seems obvious that the solution to this problem is to turn to the use of this grinder, whether the shop is large or small.

Information from: "Paying Investments in New Equipment," *H. H. Moor,* Machinery, *May, 1937, p. 583.*

STUDY 17

CARBOLOY TOOLS VS. HIGH-SPEED STEEL CUTTING

A plant is contemplating the use of Carboloy cutting tools in place of high-speed steel tools in regular production processes. Much has

been said and is known about Carboloy cemented tungsten carbide. In many instances, it has made machining operations commercially possible which without it were impossible. Production has been greatly increased on very difficult machining jobs, too, by the use of this new cutting alloy. But this information is not very useful to this plant, for Carboloy is contemplated, not for a very difficult job, but for a

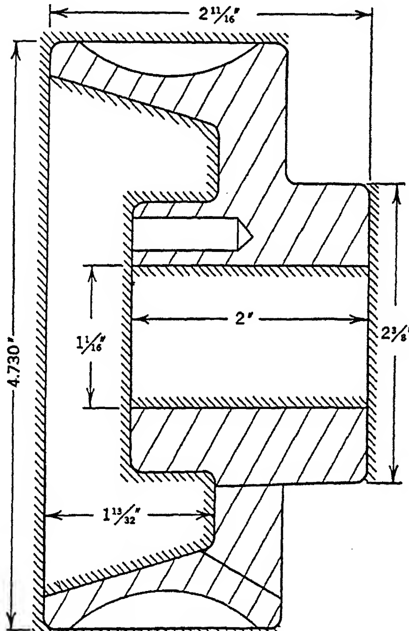

FIGURE 7. Surfaces machined with Carboloy indicated by shaded outlines.

relatively "easy" production job where high-speed steels do the job nicely at present.

Will Carboloy fit in in such a case? What are its advantages which may effect savings over the use of high-speed tools? The plant in question turns to the time study for its answer. The job will be done by both methods (Carboloy *vs.* high-speed steels); the one doing it for the least cost will go into regular operation.

The job chosen for the study was one of facing, turning, boring, taper-boring, and reaming aluminum bronze gears, the cross-section of which is shown in Fig. 7. Following is the detail of the time study taken on this operation by both cutting tools:

DETAIL OF TIME STUDY (FIRST CHUCKING)

NOTE: HS indicates figures for the high-speed steel tools.
C indicates figures for Carboloy tools.

SUB OPERATIONS

		R.P.M.	Surface, Feet	Cut	Actual Time, Minutes
1. Chuck (3-jaw air chuck)..	HS				0.15
	C				0.15
2. Index and position cutters	HS				0.05
	C				0.05
3. Start drill and face hub....	HS	74	40	Hand	0.50
	C	356	186	Hand	0.15
4. Index and position cutters and start feed.........	HS				0.15
	C				0.15
5. Core drill and rough turn (hex turret) rough face (cross slide)...........	HS	74	97	0.015	1.20
	C	356	475	0.015	0.25
6. Index and position cutters	HS				0.10
	C				0.10
7. Rough form taper........	HS	74	97	0.015	1.25
	C	356	395	Hand	0.30
8. Index and position cutters	HS				0.15
	C				0.15
9. Finish bore and finish turn (hex turret) finish face and chamfer (cross slide)	HS	74	97	0.015	1.85
	C	356	475	0.015	0.40
10. Index and position cutters	HS				0.15
	C				0.15
11. Ream.................	HS	74	20	Hand	0.15
	C	356	95	Hand	0.10
12. Index and position cutters	HS				0.15
	C				0.20
13. Finish form taper........	HS	74	80	Hand	0.15
	C	60	65	Hand	0.15
14. Remove................	HS				0.10
	C				0.10
Total Time.............	HS				6.10
	C				2.40

For a run of 400 pieces by use of each cutting tool, the following data were obtained:

	HIGH-SPEED	CARBOLOY
1. Average flat time per piece..................	6.10 min.	2.40 min.
2. Average *production* time per piece.............	7.32 min.	2.88 min.
3. Labor & overhead per piece at \$1.50/hr.........	\$0.18	\$0.07
4. Cost of cutters used up on this 400-piece lot......	\$20.00	\$20.00
5. Cutter grinding time* at \$1.50/hr.............	\$62.50	......
6. Total cost on 400-piece lot (Items 3, 4, and 5)...	\$154.50	\$48.00
7. Total cost per piece including cutter costs = Item 6/400..............................	\$0.386	\$0.12
8. Pieces per 8-hr. day including cutter grinding...	33	166
9. Pieces per year (280 days).....................	9,240	46,480

* No grinding necessary during this lot using Carboloy, but the high-speed steel cutters were ground after each 15 pieces.

It is not difficult from this tabulation to figure what the Carboloy savings will be:

1.	Savings per piece = \$0.386 − 0.12 =	\$0.266
2.	Savings per lot = \$154.50 − \$48.00 =	\$106.50
3.	Savings per year based on 46,480 pieces = 46,480 × \$0.266 =	\$12,363.68
4.	Total investment in Carboloy per year = (\$470.00 per set × 3)	\$1,410.00
5.	Total investment in high-speed steel per year = (\$50 per set × 6) =	\$300.00
6.	Added annual investment in Carboloy cutters over that of high-speed steel cutters per year = \$1,410 − \$300	\$1,110.00
7.	Net annual savings on investment = \$12,363.68 − \$1,110.00 =	\$11,253.68
8.	Earning power of additional investment in Carboloy cutters = \$11,253.68 ÷ \$1,110.00 =	1,013%/year

It is concluded that the plant should immediately change to Carboloy tooling in production since it has demonstrated its ability, not only for use on commercially non-machinables, but in materially increasing production and decreasing costs on regular production jobs. Feeds and speeds may be increased to so great an extent that the amount of metal removed in a given period, as compared to high-speed steel, is so much greater that both tool and machine operating costs are greatly reduced and production increased. Savings in grindings of tools are also economic justification of Carboloy in the regular production processes as well as on the more difficult machining jobs.

Information and figures from: Carboloy Magazine, *Vol. 1, No. 3.*
Courtesy Carboloy Company, Inc., Detroit, Michigan.

STUDY 18

THE STEAM ENGINE VS. PURCHASED ELECTRICAL ENERGY IN PUMPING

For 12 years a certain small refinery employed a steam engine to pump gasoline from storage tanks to railroad loading racks. This equipment is in good and serviceable condition today, operates reliably, and would be capable of giving service for the remainder of its estimated life of 25 years. Recently, however, refinery engineers have come to the conclusion that it would be much safer, cleaner, quieter, and more economical to substitute electrical power purchased from a utilitity whose services are available. Should such a change be made? Examination of cost detail may shed some light on this question. The company management indicates it will approve the change only if a 10 per cent return on the investment can be earned.

Twelve years ago, the steam plant was installed at a total cost of \$6000, to be retired at the end of 25 years by straight-line depreciation. Operation and maintenance of the old plant averages \$2500 per year,

including all operating and repair costs, fuel, etc. Experience has shown taxes and insurance to be 1.5 per cent of the original investment. At the present time, the best offer received for the old plant, were it retired and disposed of, is $715. On the other hand, the new plant including motors, control, and all other accessories to convert to electrical pumping will cost $9000, with an estimated life of 30 years, to be retired, if decided upon, at the end of that time by straight-line depreciation. Insurance and taxes will be approximately 2.0 per cent per year, while cost of operating and maintenance is estimated at $1100 per year.

To arrive at an arithmetic solution, and recognizing the unamortized value of the old plant, we can calculate the return on the investment necessary to change to electrical pumping as follows:

For the steam plant:

Operation and maintenance	$2500 per year
Depreciation = $6000/25 =	240
Taxes, insurance, etc. = $6000 × 0.015 =	90
Total annual cost of steam plant	$2830

For the electrical installation, recognizing the unamortized value of the plant being replaced:

Operation and maintenance	$1100 per year
Depreciation = $9000/30 =	300
Taxes, insurance, etc. = $9000 × 0.02 =	180
Amount per year book loss on old plant that must be charged to the electrical plant over the remaining life period of the old plant is: $\frac{\$6000 - (12 \times 240) - 715}{13} =$	185
Total annual cost of electrical pumping	$1765
Saving by electrical pumping = $2830 − $1765 =	$1065 per year

$$\textit{Percentage earned on investment} = \frac{\$1065}{\$9000 - 715} \text{ or}$$

From every indication, the change will very well satisfy the executives, for the return is well over that required.

This method of solution of a replacement problem, in which the unamortized value of the old equipment is recognized and charged to the new equipment, is acknowledged by some, condemned by others. One of the chief arguments against recognizing unamortized value is the fact that the value said to remain in the old equipment is a book value based upon a previously estimated life of the equipment. It is contended that had this estimate been correct, there would be no unamortized value at the time replacement is desirable; hence to use the unamortized value in the calculations is to introduce an error.

In such a problem as this, the thing we should really watch most carefully, however, is whether the new equipment is able to cover its own interest, taxes, etc., and amortization of its cost *before it becomes obsolete*, through the savings it brings about over the equipment it replaces. Obsolescence is a big factor in equipment where rapid improvement of design and efficiency is still in progress, for owners and users of such equipment find it often to their advantage to get newer and more modern equipment long before the old is worn out or reaches the end of its estimated service life.

Factors which tend toward a change to electrical pumping in this example, but which are not shown in the calculation at all, include the great increase in safety when installed in so hazardous a location, cleanliness (much desired around a refinery), quiet operation, elimination of the handling of fuel oil or coal, less attention needed, and perhaps less labor required. Remote control and ease of control, automatic features, etc., round out the arguments in favor of electrical pumping in this example.

STUDY 19

PURCHASED POWER VS. PRIVATE GENERATION

Today, there often is brought before the engineer the problem of source of electrical energy to do a certain job. Consider a small manufacturer in the Middle West starting a small factory to be electrically powered. Power may be purchased from a nearby high line, but the manufacturer has the idea that he can more profitably manufacture his own power. His demands are such that he will have a load of about 475 kw. for an average of 54 hours each week. He has decided that, in the event that he does generate his own energy, he must provide adequately for peak loads that may occur occasionally, and that he must divide his installed capacity into more than one unit to allow for maintenance, repairs, and emergencies without complete shutdown. He decides two units of 300 kw. each will provide this. His plant will be Diesel powered if such power can be justified since steam plants of small size are inefficient as compared to the Diesel. That plus other Diesel advantages led to this selection of power to drive the proposed plant.

The power rates are based upon many factors. If a user has a continuous demand over long periods of time, rates are usually more favorable. Likewise, demands of consistent starting and stopping times, or of high power factor, give lower rates for purchased power.

After studying the needs of this manufacturer, analyzing his demand, power factor, location, etc., the public utility from which power would be purchased decided that power could be furnished the manufacturer at a rate of 2 cents per kwhr.

With this figure known, the manufacturer set about to justify economically his own contentions that he could produce his own power by a Diesel plant cheaper than he could purchase it. He bases his figures upon the two 300-kw. units which are to be housed in a modern building of $12,000 construction cost. His investment, he calculates, will be as follows:

Power plant building	$12,000		
Real estate	3,000		
Total		$15,000	
Generators	$ 4,000		
Switchboards & wiring	2,000		
Engines (Diesels)	36,000		
Foundations (for generator equipment)	1,500		
Miscellaneous items	2,000		
Total		$45,500	
Oil and water storage tanks	$ 1,500		
Oil and water pipe lines	1,500		
Exhaust piping	500		
Compressors (auxiliary)	200		
Total		$ 3,700	
Total investment			$64,200
			or $107/kw. installed.

The manufacturer consulted other users of similar Diesel-power generator equipment, and, working on the assumed basis of 475 × 54, or 25,650 kwhr. per week, calculated his own annual production charges to be as follows:

Labor costs	$4,850
Operating fuel costs	7,950
Maintenance and miscellaneous	600
Production costs	$13,400 per year

If 25,650 kwhr. are consumed per week, this is a total demand of 1,333,800 kwhr. annually. Production costs will then be $13,400/1,333,800 or 10.05 mils per kwhr.

On the basis of a rate of 11 per cent, annual fixed charges on the investment will be:

$$11\% \times \$64{,}200 = \$7{,}062 \text{ or } 5.29 \text{ mils per kwhr.}$$

Total annual charges, hence, are ($13,400 plus $7,062) or $20,462, which bring the total cost of furnishing power by Diesel to 15.34 mils per kwhr.

The manufacturer has thus satisfied himself that he can build his own Diesel power plant and produce his own power for less than he can purchase it. This is not to say that the solution would be the same under any other conditions, however. For instance, had this manufacturer's load been nearer the public utility's distribution center or substation, a better rate might have been offered the manufacturer, in which event the purchasing of power might have been better economically. Also a more continuous load, a more consistent one as regards time, or a very high power factor might have enabled the public utility company to offer a rate competitive with the privately owned Diesel plant.

When a power user starts to make a selection of the most desirable source of power, he studies mainly the size and type of his demand or load, and relative fuel costs. In plants requiring heat either for "heating for comfort" or for processing (or a combination of both), steam often holds sway. Disregarding any such need for heat, we find the Diesel most adaptable and most economical for *small plants*, since small steam plants have a lower efficiency, and fuel for them is high in small quantities. This same is true in very small plants in the question of Diesel *vs.* purchased power because purchased power bought in small quantities is usually expensive. As size of plant increases, steam and purchased power begin to compete successfully with the Diesel generating plants. And, we must not fail to mention that, along with all the economical aspects and cost factors, risk of breakdown and outage for repairs and overhauling of privately owned plants must be considered. These factors may completely throw out the idea of generating one's own power—even in the face of great savings by so doing.

STUDY 20

DISTRIBUTION OF PORTABLE TOOLS

A manufacturer of portable tools, including electric drills, grinders, shears, and saws, has been selling these products through dealers in heavy hardware and automobile supplies. These outlets are established and cultivated by a few of the manufacturer's own salesmen who visit these dealers frequently. Selling literature, consisting of catalogues and price lists, is furnished them, together with popular descriptive literature for distribution to prospective purchasers. This manu-